

THE
SOUTHERN
REVUE









© Walter Scott Shinn

Thomas A. Edison.

DEDICATED BY PERMISSION
TO
AMERICA'S GREATEST INVENTIVE GENIUS
THOMAS A. EDISON

MAN, CONQUEROR OF THE EARTH AND SEA



Photo Wide World

Recently an unusual amount of salvage work on sunken craft has been undertaken in various parts of the world. One of the most important quests has been the attempt to save the £1,000,000 worth of bullion which went down in the P. & O. liner *Egypt* in the Ushant Archipelago in 1927. The vessel is lying some 375 feet beneath the surface, and this being well below the depths which had hitherto been reached by divers, a new type of suit had to be used for the purpose. This suit weighs 880 pounds, and it is claimed that with it depths can be reached far in excess of the maximum hitherto attained in diving operations. The divers have the assistance of powerful lamps.

The Book of
POPULAR SCIENCE

The Wonders of Modern Discovery
The Triumphs of Inventive Genius
The Story of all Created Things and
the World They Live In

EDITED BY

DEXTER S. KIMBALL, LL.D.
Dean of the College of Engineering
CORNELL UNIVERSITY

AIDED by a group of distinguished contributors including members of the faculties of the Massachusetts Institute of Technology, Cornell, Harvard, Stanford and McGill Universities, The Universities of Chicago, Michigan, Rochester, Tokyo, Toronto and Wisconsin, Catholic University of America, Rutgers, Vassar and Woodstock Colleges, New York State College of Agriculture and the College of Physicians and Surgeons

VOLUME

I

THE GROLIER SOCIETY

Publishers of The Book of Knowledge

NEW YORK

COPYRIGHT, 1924, 1926, 1928, 1929, BY
THE GROLIER SOCIETY

CONTENTS OF VOLUME I

	PAGE		PAGE
GROUP I—THE UNIVERSE		GROUP VIII — POWER	
TRYING TO GRASP THE UNIVERSE		MAKING THE WORLD ANEW	
Beyond the stars and within the atom . . .	17	The new powers and iron slaves of men . . .	82
UNITY IN MULTIPLICITY		MAGNIFYING OUR SENSES	
Links that bind us to sun and stars . . .	164	Amazing journeys in an invisible world . . .	237
THE ETERNAL MILLS OF GOD			
The universe, so old and yet so young . . .	303	GROUP IX — COMMERCE	
GROUP II—THE EARTH		THE CREATOR OF WEALTH	
THE BIRTH OF THE EARTH		How the world goes to market	110
Where did the world come from?	27	THE WORLD'S REAL WEALTH	
ALL THE WORLD ON FIRE		Using up the energy of the future	254
How long has the earth been spinning? . .	174		
THE EARTH'S UPS AND DOWNS		GROUP X — INDUSTRY	
Sowing the dust of continents to be . . .	313	LIFE IN THE GREAT OIL FIELDS	
GROUP III — LIFE		The mineral of the modern world	117
THE MYSTERY OF MYSTERIES		THE COTTON OF THE WORLD	
The advent and spread of life on earth . .	36	The source of the South's prosperity . . .	264
WHAT WAS THE ORIGIN OF LIFE?		THE STORY OF STEEL	
What the eye of faith may hope to see . .	187	One of America's basic industries	338
THE VERY HOME OF LIFE		GROUP XI — SOCIETY	
The cell — the unit of life	322	HOW MAN GOES ON FOREVER	
GROUP IV — PLANT LIFE		The human rebellion against nature . . .	132
WHAT THE SOIL IS MADE OF		THE FIRST HUMAN FAMILIES	
The things that made the earth fertile . .	45	The rock on which great nations build . .	287
HOW THE SOIL WAS FORMED		GROUP XII — BIOGRAPHIES	
The grinding of the rocks to powder . . .	196	NATURALISTS AND BIOLOGISTS	
HOW THE SOIL IS NAMED		Louis Agassiz — François Bichat	142
The physical wonders of the soil	331	EXPLORERS	
GROUP V — ANIMAL LIFE		Duke of the Abruzzi — Vasco de Balboa . .	296
RIVALS FOR THE MASTERY		GROUP XIII — HOUSEHOLD SCIENCE	
What the first animals were like	53	THE BUILDING OF THE HOME	
STRANGE THINGS LIKE MEN		Planning and decoration of the house . . .	155
The life-story of man's poor counterfeit .	207	COLOR PLATES	
EVOLUTION BEFORE OUR EYES			
Living creatures on the border line	354		
GROUP VI — MAN			
THE MASTER OF THE EARTH			
The most astonishing thing in nature . . .	63		
DID MAN HAVE AN ANCESTOR?			
The first known man in the world	222		
GROUP VII — HEALTH			
THE DAY OF A HEALTHY MAN			
The truth about being perfectly well . . .	73		
WISDOM AND FOLLY ABOUT HEALTH			
Is it possible for all to be healthy? . . .	230		

THE STORY OF THE BOOK OF POPULAR SCIENCE

By THE EDITOR

Copyright, 1924, By The Grolier Society

"SCIENCE" means knowledge. The sciences are the sums of human knowledge in their respective fields. Everyone has to draw on these stores of knowledge in facing every problem, simple or complex, of everyday life. The more of them he knows the better he does it. Every thinking man "wants to know". This book tells in clear language what he wants to know — about the universe, in which his world is such a tiny speck; about the earth on which he lives; the life in him and about him; the powers he has summoned to his aid; the industries he has developed with their help; the methods by which he buys and sells their products; the social relations in which his communities are organized; the health that should be his; the foods, household conditions and amenities his home life demands. The several groups into which, for convenience, its chapters are divided thus treat of astronomy, geology, biology, hygiene, botany and agriculture, physiology, physics, mechanics and engineering, invention, discovery, applied arts, commerce, sociology, household science and biography.

The Universe

Other worlds than ours

The marvel of the scheme of creation grows upon us the deeper and the further we look into it. From the astrologer of old who thought his little earth its center and a few thousand stars his unaided sight revealed to him its nearby satellites revolving round him, to the modern astronomer who sweeps the skies with his 100-inch telescope by which are revealed to him ten thousand times ten thousand stars at distances which stagger the human imagination, all bow before the Mind that could conceive and execute such a gigantic plan. What to the ancients seemed but little lanterns hung upon the vaulted roof of heaven now show themselves as suns, many of them larger, hotter, brighter than the glorious orb of day which lightens and warms our tiny planet; they roam in solitary glory through the trackless realms of space, or gather in groups and clusters that share the sky with the nebulae of gauzelike beauty or marvelous spiral structure. And each improvement in our instruments shows us still other stellar worlds with promise of further glories as yet beyond our ken. This section of our book traces the development in knowledge regarding the relations of the earth on which we live to these other heavenly bodies; shows how they have been charted, named, analyzed and even weighed and measured; tells how much has been learned about them and how much remains to be learned.

The Earth

On which we live

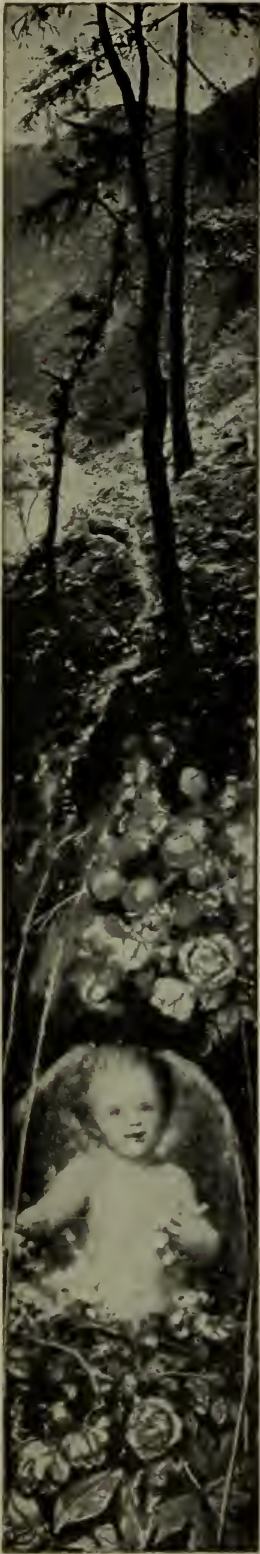
Under this heading is grouped what geology has to teach us of the history of the planet on which we live and what has evolved from the red-hot ball it once must have been before it cooled down, shrank within itself, threw off, perhaps, the dead fragment that is now our moon, and began to assume somewhat the appearance under which we know it — a sphere 8,000 miles in diameter, ridged with mountains, dented with valleys, bathed with two giant oceans and innumerable seas and lakes. Centered on this speck in space are all the physical powers that man controls; on it has happened all that his history has to tell. From it he takes his iron, his coal, his stone, his clays. Round about it surges the invisible ocean of air that supports our life and brings back the ocean waters to hill and valley so that the parched soil may smile in plenteous crops. This is the story of the shaping of the earth and the waters, of the forces which spring from the earth, and the stuff of which it is made.

Life

Life takes possession

The earth became inhabitable. Fossils reveal to us a marvelous story, as yet but partly read, of the development and spread of living forms upon the surface of our globe. For long, long ages, how long we cannot say, before man's advent on the earth, life existed in millions of homes — plant homes, keeping to the place where they were built, and animal homes, moving from place to place. For long ages life animated beings of all sorts and shapes — hideous, beautiful, monstrous, small, creeping, flying, crawling, walking, swimming; darting through the water like a minnow, dancing in the air like a gnat, joining earth and sky like an oak, crashing through the forest like a mastodon, creeping in the grass like a snake, bursting from the bud like a rose, rising to the sky like a lark, singing like a nightingale, roaring like a lion. In irresistible waves life swept through the oceans, traversed the continents, and soared on high, until sky and sea, mountain and valley and plain, became the home of millions of plants and animals, living and dying and giving birth to their kind. Then came a living creature that could think and speak and will, and knew good from evil, for at last Man was created — superior in nature though materially insignificant compared to the wild beasts many times his size and with many times his power, with which he was surrounded.





Plant Life

The magic carpet

Over the surface of the earth was spread a wonderful carpet, a thing of color and beauty that repaired and renewed itself, a universal living garment woven by the Hand that made the heavens. Except in the crater of some volcano, or on the very edge of the breaking sea, or over the rolling waves of desert sand, or at the top and bottom of the revolving sphere where everything is frozen white and still, there was hardly a spot on all the earth which this carpet did not cover. And age after age the Weaver went on, perfecting the carpet until it had assumed a million million patterns and forms, which were not only the glory of the earth, but became, with the labor of man and the coöperation of sun and wind and rain, the sustainer of the human race itself. Out of the earth come life and strength for all that live upon it. Food for man to eat, clothes for man to wear, wood for man to build his houses with, grow silently out of the earth each year. This section of our book is the story of the beautiful garden, and the wheat-field, and the mighty forest, and of all the growing plants about us, at once the wonder and the necessity of mankind.

Animal Life

The companions of man

Life, which shows itself in the beauty of the rose and the strength of the oak, is proclaimed also by the music of the song bird and the terror of the roaring lion. Greater in number than the stars that the naked eye can discern are the kinds of animals that make up dumb creation. What an amazing pageant offers this strange host! Though alike in the possession of the common attribute of life, what marvelous variety marks its different members; surprise, awe, dislike, amusement, are aroused within us as we watch the strange procession; how life varies in the bee and the whale, in the robin and the serpent, in the moth and the bat, and in the countless other forms of its manifestation in the animal world! Master of the world when brute force alone held sway, the monsters of the deep and of the plains and of the air have surrendered their lordship to man. Possessed of strength almost unimaginable, with cunning such as man can barely conceive, with endurance unmatched in any human being, they have nevertheless succumbed to the only animal that could make a weapon to serve his will. Here the wonderful tale is told — the story of the life of all

THE STORY OF THIS BOOK

created things that live and move upon the earth, except man, who has subdued them to his will, chained them to his service, won for himself even their affection.

Man A little lower than the angels

Man appears. Not the lucky outcome of blind nature's endless play with ever-changing forms of life, not the offspring of brute forebears, owning no other author or God than an "ultimate biological necessity", but the final creation of the Maker of the Universe, in Whose likeness he was fashioned. Endowed with reason from the beginning, as witness the earliest traces of his handiwork, enriched with the power of adaptation, to the most varied and changing conditions of life, he has evolved through many phases both physical and moral to his present state, remaining withal what he was essentially from the beginning, monarch of the earth. Almost insignificant as compared to the mastodon or the tiger he has nevertheless survived the one and mastered the other. He found fire and turned it to his use. He learned to sow and to reap and developed agriculture. He made a boat and began to travel. He measured time by the sun and moon, and invented written signs to express and transmit his thoughts to future generations. He gathered himself into tribes and nations and evolved complicated systems of society. In monuments and schools and libraries he preserved for his descendants the acquired stores of knowledge; as the legacy grew he came to understand more fully and clearly the nature of the marvelous forces with which he is surrounded; with boundless yearning for greater knowledge he stretched his inquiries beyond this little world and explored the heavens. All this man accomplished by means of something that no other animal has: a mind. In this section we read of man's intellectual activities and of his brain, that wonderful instrument of his soul in its operations of thought and reasoning. It is with the help of this instrument that he measures the earth and the sun and the stars, and weighs the moral worth of truth and virtue, but he has so far failed to clearly analyze the nature of its co-operation with mind. Can science tell us how he knows and remembers? Can it explain to us how the mental as well as the physical characteristics of the parents are so frequently transmitted to the child? What proof, or if not proof, what indication can science give that that which makes man what he is, his soul, will live forever as our faith in immortality leads us to assert?



Health

Man builds up strength

Here comes upon the scene our doctor, who lives to keep us well. We are made to be healthy, and there is no reason, apart from ignorance and dirt and the bad ordering of our lives, why we should be ill. We live in a world of invisible, but no less real enemies, eager to assail us, to attempt our lives. Yet millions give less attention to these things than they would to the playing of a game, and excuse themselves with the plea that in this busy world we have little time to think. In this group of chapters our doctor tells us in untechnical language how to live well — the sort of house we should live in; the truth about rest and work and play; the value of air and water and sun; what we shall eat, what we shall drink, and wherewithal we shall be clothed. We shall learn that health is ease in mind as well as in body. We shall learn the wisdom of Solomon, that "a merry heart doeth good like a medicine, but a broken spirit drieth the bone". We shall learn the wisdom of the dictionary, that "healthy" and "happy" and "holy" are three words with but one meaning. And while some of the gentlest, happiest spirits live shut-in in sick or bed-ridden bodies, there is no wealth to be compared with health, and here is health for all, the plain rules of a game in which the loser is disease and the winner is a healthy man, a healthy woman, whole of body and whole of mind.

Power

Man finds power

Man has today a million times the power he had a thousand years ago, power won from nature, snatched from wind and river and sun. He is harnessing natural forces to do the work his own hands cannot do. Here is told the marvelous means by which man, when he finds it difficult or impossible to do a thing, makes a machine to do it. He sends his messages through the air and under the sea; he hitches his engines to the rivers' horse power; he floods the darkened world with countless lights drawn from beyond the ether. Shakespeare put a girdle round the earth in forty minutes; man can do it now in two. Man can photograph a thing he cannot see; can magnify sight and speech; can store up sound. He can run like a deer, fly like a bird, swim like a fish. But he can do more, for he can travel faster than a bird, by a power that he can stop with his finger, and he can cross the earth without losing touch with home. From mid-air and mid-ocean, from down in the earth and deep



THE STORY OF THIS BOOK

in the sea, he sends his message where he will, even in the tones of his own voice. He has lengthened life, abolished space and time, and magnified the work that he can do in his allotted span.

Industry

Man uses power

The world's workshop is the world itself, and the workers are the human race. What are they doing? Millions are building machines and automobiles; millions are making and managing railways; millions are tilling the ground. Some are throwing huge bridges across wide rivers; some are stretching a telegraph wire across the desert. Some are laying the foundations of new Babylons on the site of old-world empires. Some are mining iron and making steel; some are printing newspapers and books and covering the earth with the knowledge that man has won from darkness. In this section of our book we meet the great industrial armies of the world. We see them moving masses to forward the comfort and unity and prosperity of mankind. We see the life of our factories and fields and mines. We have passing before us a panorama of the workshops of this busy world, a world alive with energy, creating, constructing, discovering, inventing, down-throwing, up-building, advancing forever from conquest to conquest, from achievement to achievement, until the whole of the man-made world is changed and made anew.

Commerce

Man buys and sells

All the world buys and all the world sells. Here we come into the world's market-place, where the United States is selling cotton, and India is selling jute, and China is selling tea, and Persia is selling rugs, and Germany is selling dyes, and Japan is selling porcelain, to all the world. How can we buy things we never touch, from men we never see, with gold that does not exist? What is this wonderful machine that no man ever sees, controlled by ten thousand men in ten thousand places, which brings what we want from the ends of the earth and takes what we make in exchange? The first man traded with bits of stick, now we trade with bits of paper: surely a simple change, yet bridging a gulf as wide as that which separates the modern man from the men who lived in caves. This is the story of the meaning of money and the power of it, of trading and carrying, of saving and spending, of the whole working





of the system — represented by the dollar in your pocket — which binds the world together in an unbreakable chain, and may one day bind it in an unbreakable peace.

Society

Man organizes society

Man was not made to live alone : Not only is the human family a naturally united group of individuals, but as far back as history can lead us, even in that dim past which archeology and ethnology are opening up to our investigation, we find men banding themselves together in tribes and groups of tribes, linked to each other by the bonds of common interests and needs. However simple and primitive may have been their social organization it contained potent elements of vast complexity and variety, and through many stages the relations of man to man, of family to family, of tribe to tribe developed into a more unified and interdependent whole, judged by more universal standards. Step by step, through generation after generation, the groups and tribes and races of mankind became the founders of the nations of the world of today. This is the story of the building up of our modern civilization. To you who read it, it is the story of your family, of the accumulated wisdom and the untiring energy of a thousand years of men which lie behind the happy home, the quiet street, the prosperous city, the united nation. It is the story of how millions of men, each with his own interest, his own ambition, his own selfishness, should live together at peace with all and for the good of all.

Household Science

Home life

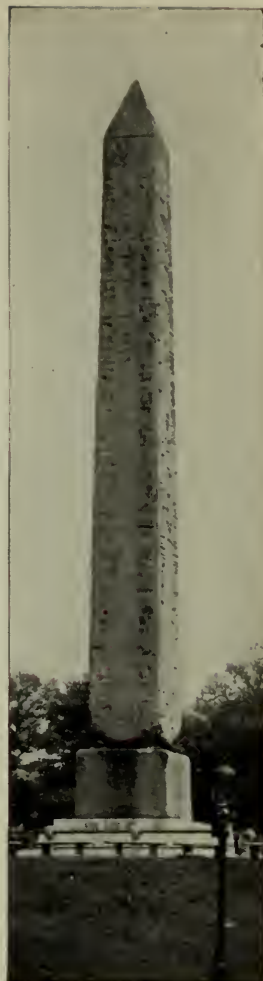
The progress of the world has been no less epoch-making in a smaller circle, the family life in the home. Conveniences our ancestors never dreamed of are taken as a matter of course. Neither matches nor gas were known to our great-grandfathers. The domestic uses of electricity and refrigeration are two generations more recent. The scientific values of foods and their proper use, preparation and conservation are but of yesterday. The harmonious treatment of the home in which we live makes for harmony in it. In this section the Domestic Science Department of Toronto University shows the way to build, equip and maintain it, and how to keep the family which lives in it properly fed, clothed and clean, and how to do it economically — proportioning the expense of each item to the joint income, in due relative amount. In short, applying the budget system to domestic use.

THE STORY OF THIS BOOK

Biography

The men of science

And if science knows no ending, it is because the men of science go on forever learning, forever probing deeper into the mysteries of Life, forever creating new instruments of knowledge and new forces making for progress. Who are these men who thus hold in their hands the keys of nature that are opening wide, and will open wider still, the doors of the Temple? Who were they who laid for us the foundation of learning, in toil and often in tribulation, during ages past? These pages introduce us to them: the thinkers, inventors and discoverers; the explorers of the earth and of the universe. Society is a partnership between all those who have lived, all those who do live, and all those who will live. All that is best from yesterday we of today must pass on for tomorrow. All that we owe to the past of the world we must pay back to the future of the world. So that we end the book with our eyes on the horizon. Wider and wider nature's doorways open, wider and wider the river of knowledge flows. Farther through the telescope, deeper through the microscope, the eyes of men peer into the mysteries of the universe. What will they see in the days that are to come? We who flash our thoughts across the sea and span the continents with our very voices, we who toil and spin with mighty instruments of power — how shall we use our leisure when the explorer of the atom chains this invisible force to do our toiling for us? That great day waits, and we can only dimly see. But the sun will rise, and men's eyes will see the dawn.



THE STREAM OF LIFE THAT GOES FOREVER FORWARD
From the painting by Mr. C. W. Wyllie.

CONTRIBUTORS

- PROFESSOR ARTHUR A. ALLEN
Cornell University; associate editor of *Bird Lore*
- PROFESSOR FRANK ALLEN
University of Manitoba
- JOHN B. ANDREWS
Secretary of American Association for Labor Legislation
- DR. MARCUS BENJAMIN
Editor, U. S. National Museum
- PROFESSOR CHARLES W. BERRY
Massachusetts Institute of Technology
- PROFESSOR SAMUEL L. BOOTHROYD
Cornell University
- DR. G. J. BRILMYER
The Catholic University of America
- REV. HENRY M. BROCK, S. J.
Weston College
- REV. JOHN A. BROSNAN, S. J.
Woodstock College
- PROFESSOR E. L. BRUCE
Queen's University
- PROFESSOR H. O. BUCKMAN
N. Y. State College of Agriculture
- PROFESSOR C. A. CHANT
University of Toronto
- PROFESSOR F. M. CLEMENT
Dean of the Faculty of Agriculture at the University of British Columbia
- MRS. A. B. COMSTOCK
N. Y. State College of Agriculture
- PROFESSOR JAMES E. CREIGHTON
Editor of *The Philosophical Review*
- HOWARD S. ELLIS
University of Michigan
- DR. GEORGE J. FISHER
Deputy Chief Scout Executive,
Boy Scouts of America
- PROFESSOR H. M. FITZPATRICK
N. Y. State College of Agriculture
- DR. LEO FRANK
General Manager, Rosebank Fur Farms
- PROFESSOR CAROLINE E. FURNESS
Vassar College
- JOHN W. HAMMOND
Journalist and electrical writer
- PROFESSOR LEON AUGUSTUS HAUSMAN
Rutgers College
- PROFESSOR MARY F. HENRY
College of Economics, Cornell University
- PROFESSOR GLENN W. HERRICK
N. Y. State College of Agriculture
- PROFESSOR R. S. HOSMER
N. Y. State College of Agriculture
- PROFESSOR RALPH G. HUDSON
Massachusetts Institute of Technology
- PROFESSOR WALTER H. JAMES
Massachusetts Institute of Technology
- PROFESSOR JOSEPH JASTROW
University of Wisconsin
- DR. DAVID STARR JORDAN
Chancellor Emeritus, Stanford University
- PROFESSOR HENRY H. W. KEITH
Massachusetts Institute of Technology
- PROFESSOR DEXTER S. KIMBALL
Dean of The College of Engineering,
Cornell University
- PROFESSOR ELLIS L. KIRKPATRICK
N. Y. State College of Agriculture
- ALEXANDER KLEMIN
College of Engineering, New York University
- PROFESSOR FRANK H. KNIGHT
University of Chicago
- PROFESSOR LEWIS KNUDSON
N. Y. State College of Agriculture
- PROFESSOR ANNIE L. LAIRD
Department of Household Science,
University of Toronto
- F. E. LATHE
Technical Assistant to the President of the National
Research Council
- CLAUDE WILLARD LEISTER
Cornell University
- PROFESSOR F. J. LEWIS
University of Alberta
- ASSISTANT PROFESSOR HOWARD SCOTT LIDDELL
Cornell University

- PROFESSOR F. E. LLOYD
McGill University
- DR. ALBERT R. MANN
Dean, N. Y. State College of Agriculture
- WILLIAM H. MEADOWCROFT
Assistant to Thomas A. Edison
- PROFESSOR EDWARD F. MILLER
Massachusetts Institute of Technology
- PROFESSOR E. G. MONTGOMERY
N. Y. State College of Agriculture
- ASSISTANT PROFESSOR CHARLES MERRICK NEVIN
Cornell University
- L. H. NEWMAN
Dominion Cerealst, Ottawa
- DR. MATTHIAS NICOLL, JR.
Commissioner, N. Y. State Department of Health
- ADOLPH S. OCHS
Owner of *The New York Times*
- DR. F. OMORI
University of Tokyo
- PROFESSOR E. L. OVERHOLSER
N. Y. State College of Agriculture
- PROFESSOR E. LAURENCE PALMER
N. Y. State College of Agriculture
- DR. J. B. PARKER
The Catholic University of America
- PROFESSOR LEON W. PARSONS
Massachusetts Institute of Technology
- T. GILBERT PEARSON
President of the National Association of Audubon Societies
- REV. EDWARD C. PHILLIPS, S. J.
Late Director Georgetown College Observatory
- REV. WILLIAM F. RIGGE, S. J.
The Creighton University Observatory
- KENNETH C. ROBINSON
Formerly Massachusetts Institute of Technology
- PROFESSOR JOHN J. ROLBIECKI
The Catholic University of America
- PROFESSOR GEORGE E. RUSSELL
Massachusetts Institute of Technology
- HAROLD M. SMART
Cornell University
- DEAN FRANKLIN SMILEY
Cornell University
- PROFESSOR ROBERT H. SMITH
Assistant Professor Massachusetts Institute of Technology
- GUILFORD L. SPENCER
General superintendent of manufacture, Cuban-American Sugar Co.
- PROFESSOR THEODORE H. TAFT
Massachusetts Institute of Technology
- PROFESSOR W. P. THOMPSON
University of Saskatchewan
- WEBSTER P. TRUE
Editor, Smithsonian Institution
- DR. FREDERICK TUCKERMAN
M.D., Harvard, 1882; Ph.D., Heidelberg, 1894
- MARTHA VAN RENSSELAER
Director of the College of Economics, Cornell University
- DR. CHAS. S. VENABLE
Former Assistant Director, Research Laboratory of Applied Chemistry, Massachusetts Institute of Technology
- REV. BERARD VOGT, O. F. M.
St. Stephen Monastery, Croghan, N. Y.
- HERBERT T. WADE
Editor of the *New International Year Book* and Managing Editor of the *New International Encyclopedia*
- PROFESSOR W. F. WILLCOX
Cornell University
- PROFESSOR ROBERT E. WILSON
Massachusetts Institute of Technology
- PROFESSOR ALLYN A. YOUNG
London School of Economics and Political Science

INDEX BY
DR. FLORENCE D. JOHNSTON
Librarian American Medical Association



TRYING TO GRASP THE UNIVERSE



THE ASTROLOGER — from the painting by Seymour Lucas, R. A.

TRYING TO GRASP THE UNIVERSE

The Marvel of Creation that Grows More
and More the Deeper we See into It

BEYOND THE STARS AND WITHIN THE ATOM

THE little child first looking up to the heavens at night stretches forth his tiny hand to grasp the moon, for he would like to have that pretty circle to play with; but soon his failures teach him the moon is beyond the reach of his arm. As the child grows he no longer seeks to hold the moon in his hand but a greater yearning springs up within his soul and he endeavors now to grasp by his mind not only the moon but the sun and planets and all the countless throngs of stars that enrich and glorify the firmament. It is a noble endeavor and a humbling one; as our knowledge grows our minds are broadened by companionship with God's creation, while the ever increasing vistas of new knowledge to be had and the realization of the incompleteness of most of our theories and the utter incorrectness of many of them, teach us to beware of proudly thinking that we are either omniscient or infallible. Throughout the pages of this work the endeavor is made to present as far as possible the well established facts of natural science; to review and appraise the theories and hypotheses that have at various times been advanced to explain and coördinate the facts, and to give an historical account both of the successes and of the failures of man in his search for the truth about the material universe.

The first impressions we receive of this universe come to us through our senses. To him who unthinkingly treads the solid ground nothing can seem more firm, more immovable than this earth of ours; to man's bodily eyes unaided by the vision of his mind, the earth which he inhabits,

the very spot on which he stands, even he himself, is the center of all things; immovably fixed in space, the earth enjoys the service of the greater light that rules the day and the lesser light that rules the night; these and those other countless lights of the sky rise and set and move in majestic circles round about the earth, their fixed center. Thus arose the geocentric theory of the universe, which in its more developed scientific form is commonly called the Ptolemaic system. It ruled the science of astronomy for over fourteen centuries, though now and again there were exceptional thinkers, such as Aristarchus, the Alexandrian astronomer (310-250 B.C.), who questioned this oldest and most obvious of theories; a new era however was ushered in when Niclas Kopernigk or Nicolaus Copernicus (1473-1543), a learned Polish ecclesiastic, introduced once more the system suggested by Aristarchus and, by faithful and minute comparison of the theory with the facts, showed that all the motions of the heavenly bodies could be explained more reasonably and naturally by supposing that the earth is not the fixed and immovable center of the universe, but that it with all the planets revolve in orbits about the sun their common center, and that the earth rotates daily on its axis, thus producing the apparent diurnal rotation of the starry heavens. His theory was received by many with enthusiasm but combated by others with vigor and even bitterness. A little later the Italian philosopher Giordano Bruno (1548-1600) still further extended the departure from the geocentric system by teaching that as the earth is but one of a

THIS GROUP EMBRACES THE SCIENCE OF ASTRONOMY, BOTH OLD AND NEW

number of planets dependent on the sun, so also the sun is but one of many similar bodies, each having perhaps its own planets; these bodies similar to the sun are the stars which seem inferior to the sun only because they are so vastly far removed from us. Bruno's fiery character and sarcastic pen, combined with pantheistic views of the universe, served rather to retard than to help the acceptance of the Copernican system; it was not until the indefatigable labor of Tycho Brahe (1546-1610) in observational astronomy had been crowned by the equally indefatigable labor of Kepler (1571-1630) in analyzing and systematizing these observations, that the learned world gave to the Copernican theory its whole-hearted adhesion, an adhesion that was both strengthened and enlightened by the new discoveries made possible through the remarkable invention of the telescope by Galileo (1546-1642).

Theories that once were novel have now become everyday commonplaces

These theories were very novel three centuries ago, but have now become commonplace, and we sometimes forget that they give us a broader, truer, more inspiring idea of the universe than was contained in the older views. All the discoveries made since the days of Copernicus have conspired to show the truth of the new theories, and what was at first but a probable hypothesis has now grown to be a well proven fact. That the earth is one of a company of planets, such as Venus or Mars, some nearer to, some farther from, our common sun, we now not only surmise but know; that the sun is a star and that the stars are suns like ours, we also know; that the stars have planets like our planets we do not know, though many surmise it to be so. By means of the spectroscope we have analyzed the substance of the sun and stars and find them to be made of elements familiar to us here on the earth; we have questioned their motions and have found strong reasons for the persuasion that the same laws of gravitation bind star to star as bind earth to sun or ourselves

to earth. The idea of a true stellar universe, having a true principle of unity, is established. But no man can think so far and realize this much without wishing to know more; and our minds keep on asking further questions which as yet we cannot answer and to which perhaps science will never give an answer. But the mind being made for truth, not simply for a little bit of truth but for boundless truth, will never be satisfied with the limited amount of truth science can unfold to it; hence whatever progress science makes, man will ever ask new questions and make new journeys into the realms of knowledge. At times we almost think we have reached the goal and have grasped the furthest member of the starry heavens, but just then it is that new tools open up new territories wherein the mind can roam still further.

Not all the wonders of creation to be measured by their magnitude

But the astronomer peering out into distances that stagger the imagination must not be allowed to make us think that all the wonders of creation are to be measured by their bewildering magnitude. When we have swept the heavens with the telescope and have had our minds broadened by the view of the vastness of nature, we should then try to look inwards that we may have our minds deepened by contemplating the complexity of even the minutest things of nature. We shall find that the universe is as wonderful in its minuteness as it is inspiring in its vastness; and we shall humbly admit that we can never hope to fully grasp it by ourselves. No one realizes better than the true scientist the wisdom of Solomon's judgment that God hath made all things good in their time, and hath delivered the world to our consideration, in such wise that man cannot find out the work which God hath made from the beginning to the end. And realizing this he knows that he has never fully accomplished his task but struggles on to a fuller and deeper knowledge both of the outward greatness and the inner complexity of this wonderful world of ours.

This latter task of unraveling the complexity of things has its degrees of refinement; analysis or anatomy, loosening apart and cutting apart, may be done by the knife or the fingers, up to a point. We may invoke lenses to enable us to see detail, say in the structure of steel or of a snowflake, which the naked eye cannot see. But, indeed, our microscopes and ultra-microscopes take us scarcely any appreciable distance inwards. If we are really meaning to reach the innermost, entirely different methods are necessary, compared with which the microscope and the telescope may almost be called crude; and these methods involve

a process which is subtler than sheer seeing, whether it be something under our noses or in the remoteness of the sky. We are compelled to do our separating and identifying of the minutest things in the universe by subtler means than these, and to see the results by the mind's eye alone.

The chemist analyzes or loosens apart, as we may analyze or loosen apart a piece of blotting-paper, but he does it with a minuteness which transcends vision, and his description of results must depend on argument and inference. Those who will only believe

what they can see — though there are, of course, no such persons, whatever they may fancy, and, if there were, one would reply, with the old Quakeress, "How does thou know thou hast a brain?" — will answer

"Fudge," when the chemist declares his faith in atoms and molecules and electrons, or the physicist his faith in the ether; but we may ignore such persons here. Only we must clearly understand what we are about.

The botanist who describes the structure

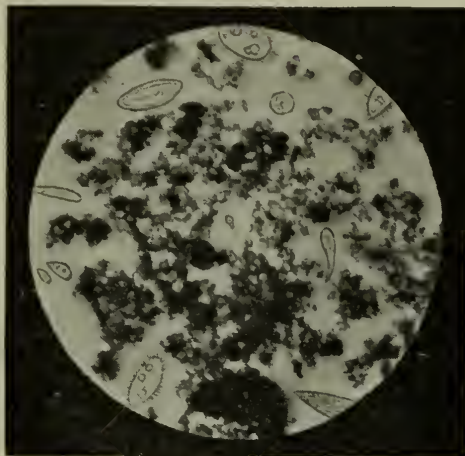
of a flower is in a happier case than the chemist who describes the structure of an atom; and we and he have to remember that we are inferring and interpreting, not seeing, and that we may require to make a re-interpretation at any moment, which will alter, in kaleidoscopic fashion, the vision which we had formed in our mind's eye. Such a re-interpretation, which goes to the very roots of

chemistry and alters half the established notions of ordinary thinking, has been made necessary in the course of this young century, and has given us entirely new ideas of the inwardness of things. Radium has been the revealer, but we shall never understand what it has revealed until we

know how far chemistry had gone before a new epoch was made by this new revelation.

We shall come later to the chemistry of the skies, but it is necessary here to allude to that question because of a reasonable and important objection which the thoughtful

student will here interpose. We propose to study a drop of water in our study of the universe. But "how on earth" do we know that this matter of water is more than a matter of earth? What right have we to



A DROP OF WATER FROM A POND
As it is seen under the microscope.



THE DISCOVERERS OF RADIIUM—M. CURIE AND HIS WIFE

THE BOUNDLESS UNIVERSE — AS FAR TO



Beyond the senses of man lies a vastness of wonder ever revealing new marvels to the human mind. This picture shows a man looking through a telescope at the dot of light just beyond the lens—all that he can see with his naked eye. The increased power of the telescope reveals the clusters beyond; and the great cluster in Hercules, so distant that the light of these stars takes thousands of years to reach us.

THE INNERMOST AS TO THE OUTERMOST



This picture shows a man looking at the spot near the microscope — all that his naked eye can see. The microscope enlarges it and reveals a second spot, and a still higher power reveals a little creature of the sea, a radiolarian, while the second spot appears as a smear of blood. As the power is increased, the radiolarian grows in size, cells of the blood appear, and microbes come into view, until the full power of the microscope is reached, revealing a world of wonder equaled only, perhaps, by the wonder still beyond.

suppose that in studying a drop of water we are studying a true sample of the universe? To this the brief reply is that by a sequence of wonderful inquiries and inventions the chemists, working in conjunction with astronomers, have found that the materials which make up the earth make up also the heavenly bodies. Scarcely any materials whatever have yet been found in the sky which we do not know on earth.

What the microscope reveals to us in a drop of water

Even when chemists find a new kind of stuff in the sun, and call it helium, a few years later they find it upon the earth as well, so that it might just as well be called terrestrium.

Every possible mode of inquiry, affording copious and varied evidence, assures us that in studying a drop of water, or any other specimen of our world, we are studying the universe, no less than if we had specimens of Sirius, Jupiter, and Halley's Comet under our fingers. The drop of water may first be studied by the microscope, which will detect dust and microbes and other things which are not water. If these things be removed, the microscope can help us no more, except for its clearer demonstration of the forms of frozen water — ice, hail, and snow. The limit of seeing has been reached.

Here the chemist comes and tells us that the water is still impure, because all manner of gases, obtained from the air, are dissolved in it. It may look very flat to our eyes, but the chemist knows it is still aerated. However, perhaps the gases can be removed, and now we have, at last, a really pure specimen of distilled water — water that is therefore gasless — to study.

The "treacherous element" which is not an element at all

This appears to be so simple and unchangeable a thing that we call it "an element" — "the treacherous element," "the mercy of the elements" — to this day, as Aristotle did more than two thousand years ago. The chemist, notwithstanding, proves to us that we are wrong, and that water is made of two things, not two fluids,

as we should expect, but two gases, neither of them in the least like water. These gases, oxygen and hydrogen — hydrogen meaning watermaker — the chemist calls elements, and he assures us that water is not an element at all, nor even a mere mixture of elements, but that it is a specially constructed compound of the two elements in question. These two, however, and many others, are really elements, he declares.

All this involves a great deal of discussion and experiment, and we are for the present merely outlining it, on our way to what is our new and special concern.

Eighty things combining in a million ways to make the world

We observe only that the chemist describes and names some eighty different kinds of stuff, including oxygen and hydrogen, which he calls elements; and declares that the earth, in all its variety of light and heavy, gas, liquid and solid, black and white, metal and mineral, even also the bodies of all living things, are made up of these elements, either existing unmated with each other, or combined in a thousand — say, rather, in a million — ways to form compounds, of which water is almost as simple an illustration as can be. The astronomer declares that this view, which chemists first alleged of the earth, is true wherever the telescope and its allies can peer. It follows that we must push our studies in this inward direction as deeply as ever we can; and if we go deep here, we are also going deep everywhere.

How each element is made up of a number of tiny units

If we can obtain a specimen of an element by itself — oxygen, gold, or any other — we find, say the chemists, that it is made up of a number of tiny units called "atoms." All the atoms of any element are the same, and they are always the same; while, of course, the atoms of any element are different from those of any other element. Indeed, the reason why gold is gold and not iodine is that its atoms are gold-atoms, and those of iodine are iodine-atoms.

Further, a vast part of the power and activity of the world, and of living things, is due to the way in which atoms of one element will unite with those of another, making compounds like water, or iodide of gold, which is formed when iodine-atoms link up with gold-atoms. This power or energy is called "chemical energy," and it is what we obtain in all the processes of burning, whether fuel in a power station for electricity, or food in our hearts for life. And all this—as we must observe now, or we are lost—is what happens *between* the atoms. Not a word of *within*.

So far chemistry had reached; and this is the accepted chemistry of the schools and the textbook today, perfectly true so far as it goes. But the instant we suppose it to go farther than it does go, the true becomes false in our hands. And this, unfortunately, is what most chemists did. Only very rare, great men, among them Mendeléef, declined to accept the view that gold-atoms and oxygen-atoms, and the other eighty or so kinds of atoms, have always been what they are, were made as they are, will never be anything else, "the foundation-stones of the material universe, which have existed from the creation, unbroken and unworn."

To us, today, these words, from the latter part of the nineteenth



THE WONDER BEYOND OUR EYES
The architecture of a snowflake.

century, sound as remote as if Athenian lips had uttered them. And it is by the light of radium the revealer that we have been enabled to lay the atom—that is to say, the *not-cut*—upon the dissecting-table, and subject it to our anatomy, its proud name notwithstanding. This is an achievement of the first order in itself, and will occupy other pages of this work; here it concerns us not from the point of view of the chemist or the student of electricity, but because it lifts a veil hitherto impenetrable. It is a discovery which has enabled us to see deeper than the atom, to pierce to the inwardness of the universe, not only as we could never do before, but as we did not know could be done—a discovery which enriches our minds with an idea of the universe which is no less precious, and no less necessary in our essay towards completed truth than the work of Copernicus and the idea of Bruno. If we doubt it, let us proceed. No matter whose good guidance we follow, no matter what the penetration and courage of our minds, we shall ere long find ourselves lost, baffled, peering into the beyond; the minute things of nature seem harder to grasp than the vast things. The astronomer may always hope for a bigger telescope, a finer lens, a more sensitive camera, but when we have peered our deepest into the atom we

shall realize that our next need is of bigger minds; and in this strait the beneficence of such princely givers as Lick and Yerkes and Carnegie, however magnificent, is of no avail whatever.

Radium led the way in perfectly straightforward fashion. We have seen that power and energy, such as light and heat, are commonly obtained from combination between atoms, as when carbon is burnt in oxygen; and we might have added that they must always be obtained from somewhere. Radium produced light and heat, and produced light and heat continuously, not to mention here its production of many other things.

The idea that radium caught up the force of the air and used it

Now, the great chemists who first discovered radium proved that it is an element. It is made up of radium-atoms, as carbon is made up of carbon-atoms. But a piece of carbon, left alone, produces nothing: we get light and heat only when we burn it. Radium, left alone, liberates a tremendous quantity of energy of various kinds for as long as we choose to watch it, and scarcely seems the poorer for its prodigality.

But anything may give forth light and heat by simply reflecting them; and radium might be doing this in a less direct way. The air is always in motion. Its atoms fly about at great speeds in all directions, however still it may appear to us. Radium might be so made that it could take up the energy of the atoms of air which hit it, and turn this energy into light and heat. This was an excellent idea, and certainly had to be disposed of before we could believe anything less probable.

But this idea was disposed of. Experiment showed that radium went its course, and did its deeds at its own pace, without reference to any changes in the pressure or temperature or quality of the gases to which it was exposed. Its force came from within. Some people suppose, similarly, that outside forces, happily arranged, push upon people and make them into geniuses.

Radium, the genius among the elements, revealing to us the atom

But they do not. The genius gets his force from within; and the difference between him and other people is that he was born different. Just so are the atoms of radium born different from the atoms of carbon; and just so, as we have lately learned, to the astonishment of every chemist in the world, do they get their power from within themselves. Radium is the genius among the elements; and the best service of its genius is the familiar one of throwing light on other and common things, making us understand everyday atoms as Shakespeare makes us understand everyday people such as ourselves.

The property of radium, by which it produces radiance and other things from within itself, is called "radio-activity"—a clumsy name which is to be learned because it is now one of the most important names in science. For, indeed, the first fact we discover about this radio-activity is that, when carefully looked for, it is to be found, in greater or less degree, practically everywhere. We may argue that this is due to minute traces of radium being almost everywhere, and that is largely the explanation. But the whole explanation includes the discovery that the atom of radium is not unique in its powers, though unique in their extent.

The complex and powerful forces locked up within all atoms

In a word, atoms are not atoms, but are complicated structures—some more so, like those of radium; others less so, like those of hydrogen—which are endowed with their own internal stores of energy. To some considerable extent it can be measured, and the measurement provides us with an almost incredible result. The various forms of energy hitherto known in the universe, such as those involved in the chemical union between atoms, or in the action of gravitation, all the energy of visible motion of all kinds, and of what is called "molecular motion"—the motion of molecules, or groups of atoms, in a gas, or elsewhere—

the energy of magnetism, of heat and of light, and other forms of "radiant energy," as it is called: all these are eclipsed, surpassed, ranked as trifling, by the discovery of a source of energy which was wholly unknown until the other day.

The atom, which we thought of as played upon from without, but itself stable, stolid, as we think of a grain of sand, is indeed the reservoir of by far the greater part of the powers of the universe. This intra-atomic energy, contained *within* the atoms, and not derived by action between them, transcends all other known forms of energy put together; and its discovery marks a new age in the history of our understanding of the universe.

The lesson taught by radium gives a new idea of the power of the universe

We have thus already been taught by radium a lesson which is not unworthy to compare with the lessons of astronomy, though much more is yet to follow. Astronomy has taken old ideas of the world, with the earth as the center of all things, and the heavenly bodies as its attendants, and has given us a new idea of the size of the universe by teaching us that ours is one of a company of worlds. The modern study of radium, of radio-activity, and of intra-atomic energy has done no less for our notions of the power of the universe. We have marveled at the force of explosions, at the motions of the "flying stars," at the "crash of worlds," at the speed of light, and the transformations effected by heat; and now we learn that these are small compared with forces which we had never even suspected to exist.

This discovery is of the highest theoretical importance, as giving us a far deeper knowledge of the constitution of matter, but it has a very practical bearing also. All our daily needs, our industries, our amusements, our intercourse with other peoples and our knowledge of other lands, depend very much upon our supply of power. We now look chiefly to coal for this power; but we know that the supply of coal is limited and that at the present rate it cannot last so very long. And just as the fear of a universal shortage of the

sources of power is confronting us we learn that within the atoms we possess a much greater quantity of energy than would be supplied by burning all the coal in the world. We have it in our hands; we are rich indeed in power, *if only we can use it*. We know it is there, locked up in the atom, but who will give us the key to the safe? Many men throughout the world, in university, technical, industrial and private laboratories, are working devotedly for the purpose of finding that key; our confidence in human ingenuity makes us hope that they will find it. When they do, who but the curator of a geological museum will bother himself at all about coal?

Such is the revelation and such the prophecy of radium, so far as the energy of the universe is concerned, but energy will not be lacking from these chapters till the tale of them is complete, and here our immediate concern is less with the energy bound up in the atom of radium — or any other kind of atom — than with the minute structure which is now revealed.

Like a period from this page flying about in the national capitol

The atom has parts, even separable parts; it has an architecture, like a cathedral or a nation's capitol. It has been estimated that the size of its constituent parts, compared with the size of the atomic building itself, is like the size of a printer's period compared to the national capitol. So that an atom, we must observe, is really a dynamic building, and its constituent parts, so far from being laid in their places, never to move therefrom, are in active motion all the time.

But we are passing into the inwardness of things with little appreciation of the length of our journey. Lord Kelvin estimated that if we could magnify a drop of water to the size of the earth, its constituent atoms would be of a size somewhere between that of small shot and baseballs. We must seriously try to imagine the number of marbles, say, in a sphere as big as the earth; and then we may feebly conceive of the minuteness of the atoms that compose a drop of water. When we have accomplished this impossible feat,

we may think that we have done well, and, indeed, when Lord Kelvin made his comparison, he was seeking to show how minute were the minutest of all things, those atomic ultimates beyond which we could not go. But the twentieth century places any one of these inconceivably minute ultimates — so called — before its mind's eye, and asks us to regard it as itself a relatively huge structure, composed of more ultimate ultimates, which bear to it the proportion of a pin's head to the capitol. It is evidently further to the innermost than we supposed.

A solar system of wonder packed into each tiny atom

And, indeed, a recent comparison, which is probably much more than a mere comparison, and expresses something like the facts of the atom, helps us to see the justice of the view that our inward journey into things is just as far as our outward journey was. There is good reason to compare an atom not to a building merely, but to such a structure as the solar system, with its central sun and its attendant planets ever flying thereabout, kept in their places by a force of attraction which runs between each of them and the sun. These planets are, of course, very tiny compared with the distances between themselves.

The earth, a few thousand miles across, is scores of millions of miles from its nearest planetary neighbor; and if we go farther outwards from the sun we find that the distances between planets run into hundreds of millions of miles. The mean distance of Uranus from the sun is 1780 millions of miles, and its outer neighbor Neptune is a thousand million of miles beyond it.

The real atoms within the atom called "electrons"

And now the chemists and the physicists tell us that in the atomic system the planets, if we may call them so, are relatively as far apart from each other as the planets of the solar system. Our journey, therefore, to the central sun of the atom — if such, as is probable, there be — is no mean feat, since we begin outside the atom al-

together. It is like the journey of a comet which enters the solar system and travels all the distance from Neptune to the sun before its work is done.

Our work is not done. We have entered the atom in bold and cometary style, and found it spacious and marvelous. As we approach the atomic sun our rate of progress quickens, as a comet's would, but we have not reached it yet. Indeed, we are much preoccupied with the bodies we meet on our way — as a comet may become preoccupied with Jupiter's attraction, and never reach the sun at all. These bodies we meet on the way have such amazing properties, so utterly out of proportion to their tiny size, and are yet so elusive and insubstantial when we try to grasp them in the mind's hand, that they may well occupy us for years to come.

These real atoms within the atom, of which much more must be said in these pages, are called "electrons." They move in their orbits inside the atom with amazing speed, compared with which the speed of a flying star is almost nothing. These move at the rate of scores of thousands of miles in a single second. They each carry a charge of what is called negative electricity, and it is probable that, while each repels all the rest — which is just the opposite of what happens among the planets of the solar system — they are held together by their common attraction to a center of some kind, which has a charge of positive electricity. When this bond partly or wholly breaks, the electrons are released, as when radium atoms explode, and the atom breaks into smaller pieces. The energy within the atom seems therefore to be electrical, belonging to the same order as the electrical energy that we know, but its total amount beggars our imagining.

Whether we go outward into the vastness of the sidereal universe or inward into the atomic universe, we find newer and newer marvels awaiting our minds; and knowing that all created things must have an adequate cause for each and every one of their perfections, we are forced to exclaim how wonderful must be the Author of all these marvels! how great is the Creator of the universe!

THE BIRTH OF THE EARTH

The Amazing Beginning of the Flying Ball on
which we Ride Thousands of Millions of Miles

WHERE DID THE WORLD COME FROM?

COMPARED with the colossal world he inherits and inhabits, man is a pygmy. Three acres and a cow suffice to feed him; six feet of earth suffice for his last resting-place.

How, then, could our early ancestors obtain any adequate notion of the shape and size and character of the planet which whirled them round the sun? They had no telescopes, no automobiles, no ocean liners, no airplanes; how could they, with eyes, and legs, and chariots, and coracles, get any idea of the nature of their terrestrial home? Knowing the world but fragmentarily, they fancied it flat like a pancake, and thought it stood still in the center of crystal spheres which carried the moon and the planets round it.

Of such small conceptions of the world the literature of primitive peoples is full. The Hindus imagined the earth borne by a huge elephant standing on a gigantic tortoise swimming in a sea of milk; and even the wise Greeks ended it at the Pillars of Hercules, and surrounded it with a misty world of dreams, where golden apples grew in enchanted gardens, and lotus-eaters were "propt on beds of amaranth."

It was inevitable, perhaps. Even now, in these "days of enlightenment," we do not know so much about our planet as we might. An educated man was recently asked how many miles the circumference of the earth measured, and he guessed about fifteen thousand, though every school-boy ought to know that it is almost ten thousand more. Nor is it at all an uncommon thing to find people, supposed to be educated, who believe that the moon shines by its own light.

The astonishing thing is, not that men should have had wrong theories, but that they should have had the courage to theorize at all on such tremendous and bewildering themes.

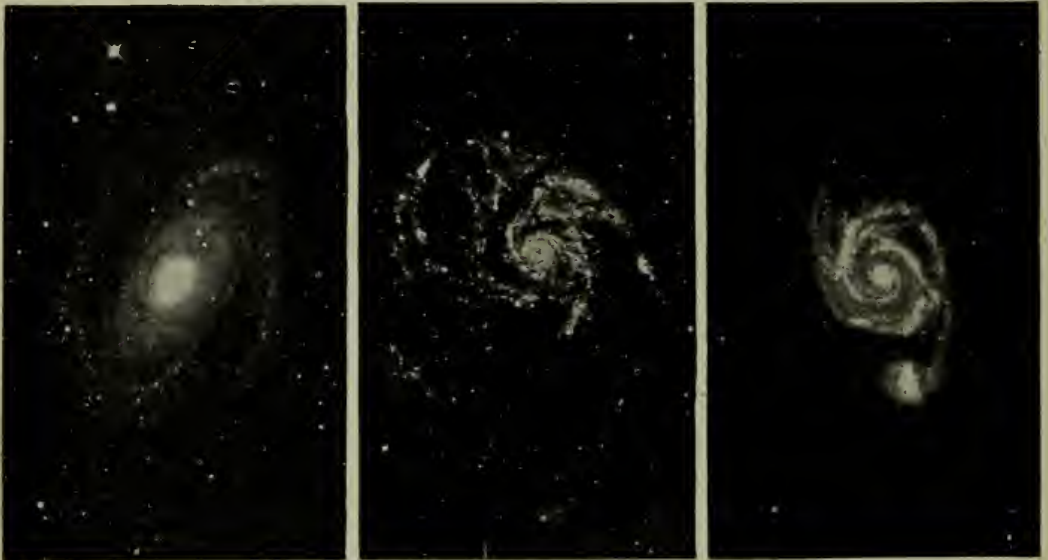
But from all time little men with big hearts and minds *did* tackle such problems; and though their first attempts were bound to be imperfect, yet by degrees, in one way and another, they found out very many things about the great planet on which they lived.

Nor were the big hearts and minds content to know the world merely as it is—the human mind, by the force of its very nature as an instrument for seeking truth, is ever insistent in its demand for the reason why of things; each step backwards or upwards, though helping it on its quest, serves yet more to whet its desire for truth until the first source and the ultimate goal of all truth as of all being is reached, the Creator Who is at once the cause and the exemplar of all the perfections of His handiwork, which we call the universe. The fuller knowledge of God Himself is the proper object of philosophy and religion; science has a more limited though still most ample scope and is content to investigate His creation as it is and to reason back to the various physical states through which it may have passed into its present, though still changing, perfection.

It is, therefore, both quite natural and eminently proper that we should seek, as men have ever sought, to see this earth of ours as it was in its babyhood, to discover as far as we can when and whence it came, and how it grew.

It is quite certain that the earth has not always been in its present condition. Day by day, year by year, we can watch the surface of the world changing. We can watch mountains tottering, glaciers dwindling, islands upheaving; we can watch ice and snow, and tornado and sea, and earthquake and volcano at their destructive and reconstructive work; and geology teaches us that such changes have been occurring for ages that we cannot count. We find the remains of ferny tropical forests amid the arctic and antarctic ice; we find the signature of glaciers on the rocks of

candescant gases. At first the mist of fire extended beyond the outermost planet of our system — that is to say, beyond Neptune. Its diameter must, therefore, have been over six thousand times the present diameter of our sun. The mist cooled and contracted, and as it contracted, it spun faster, according to a well-known law. Now, if we twirl a mop faster and faster, the water begins to fly off, and so, as the rotating fire-mist spun faster, it flung off a ring of substance much like Saturn's belt. The ring spun for a time, but soon broke, and collected into a big



WHAT IS HAPPENING IN THE HEAVENS NOW — PHOTOGRAPHS OF SPIRAL NEBULÆ

These photographs of sights that may be seen today through a telescope illustrate the way in which it is supposed the sun and the solar system were evolved; and they show, too, especially the center picture the throwing off from a central body of huge masses, vastly bigger than our earth, which may be forming into new suns and solar systems.

pastoral lands; we find sea-shells on mountain-tops and cities under the ocean.

Where, then, did the earth come from, and in what shape did it first appear?

About a hundred and fifty years ago, the superbly audacious nebular hypothesis blossomed in a few great minds, and round this hypothesis cluster all the hypotheses of the making and shaping of the earth. The idea was advanced in various forms by various thinkers, and is fully described in another part of this work, but here we may give an idea of its broad features as Laplace conceived them.

According to the view of Laplace, all the members of the solar system were originally blended in a whirling mist of in-

rotating ball — the planet Neptune. As the nebula still contracted, and still spun ever faster and faster, other rings were formed, conglomerating into planets, and one of these was the earth. The earth, of course, continued its spinning, its cooling and contracting, and one day as it contracted it threw off what is now the moon.

A Belgian scientist invented a very ingenious and striking way of illustrating this nebular suggestion. He floated a ball of oil in a mixture of water and spirits of wine, and contrived to make the oil revolve. As the ball of oil revolved, it bulged at its equator and flattened at its poles, and when it was made to rotate more rapidly it threw off successive rings

of oil which broke and formed balls that rotated on their own axes, and revolved round the central ball of oil.

According to this audacious and magnificent notion of Laplace, the earth, the sun, and all the planets were first incorporated in one tremendous cloud of fire, and the earth was once a belt round the waist of the whirling sun. The idea is in accordance with many of the facts, and certainly appeals to our imagination. We find Saturn at present wearing belts somewhat similar to those Laplace described, and we find space filled with glowing nebulae some of which give indications that they are slowly revolving around an axis. Still, modern scientists have found that the hypothesis is not entirely satisfactory, and many modifications and amendments have been proposed.

Among the more noted modern theories is the so-called "meteoric theory," which was so enthusiastically championed by Sir Norman Lockyer, who held that the planets were built up from fragments of meteors. Between the planets of our solar system are swarms of stones and broken meteors swiftly moving in all directions. When the larger fragments enter our atmosphere, friction with the air renders them incandescent, and if they are large enough, we see them as what we call "shooting stars." It has been calculated by Professor Newton that about twenty million meteorites, each large enough to be seen as a shooting star, enter our atmosphere every twenty-four hours, and the sun is probably pelted with them. Many of the comets, too, are probably swarms of stones.

The meteoric hypothesis supposes that nebulae are not incandescent gases, but swarms of such stones banging about in an atmosphere of hydrogen. The stones dash hither and thither, colliding and clashing against each other. Some are converted into gas, some into molten metal, by the heat of the collision, and gradually they come together in larger stony masses, which attract other stones by gravitation.

The exact way in which the planets are formed and set in their courses has not yet been worked out by the believers in this hypothesis. Some hold that the stones dart about in all directions; others be-

lieve that they revolve in definite orbits round a central mass, and collide only where their orbits intersect. This latter point of view, which has much more probability than the former, has been very carefully developed by several scientists, especially by Chamberlin and Moulton, and is known as the "planetesimal" or "planet-

oidal" hypothesis because the original elements that finally unite to form the present system are supposed to have had definite orbits and hence to have been little planets or "planetesimals" from the start. In any case, the ultimate result is a number of molten massive bodies.

Whether we choose to believe that the earth was formed from a cooling fire-mist, or from a hailstorm of stones, our imagination must be kindled by the sublime audacity of the conception. Equally wonderful is the picture of the earth emerging from a fiery cloud, or the picture of the earth battered and bombarded into existence by volleys of red-hot stones dashing and clashing against each other.



DOES THE PACIFIC OCEAN ROLL IN THE BED OF THE MOON?

One of the theories of the making of the earth, not widely accepted perhaps, is that when the earth was pear-shaped, centrifugal force wrenched off the point of the pear as it whirled round and round, making a huge hole about 27 miles deep, in which the Pacific Ocean now rolls.

One more suggestion may be mentioned before we leave the subject. A few years ago Professor J. H. Jeans proved mathematically that a spherical nebula slowly revolving in a hot state must assume a pear-shape as it contracts, since it will cool more quickly on its surface, and must revolve more rapidly as it shrinks, and that eventually there would be a tendency for the pear-point to fly off, especially if attracted by passing bodies; and so the consecutive formation of the planets might be explained, particularly the birth of the moon.



HOW THE EARTH SHRANK DOWN

The earth, if it evolved from a gaseous nebula, must have been many thousands of times its present size before it cooled down enough to be the home of life. This picture shows its probable appearance as a globe of fiery gas; the small dot below represents the earth as we know it, now that it has shrunk within itself.

According to this suggestion the earth was at one time a pear-shaped mass of molten matter, whirling round the sun, and the pull of the sun wrenched off the point of the pear, making a huge hole about twenty-seven miles deep, which has since become the bed of the Pacific Ocean. There is an opportunity for the imagination — the blue Pacific singing and surging in a scar in the earth's side, whence was torn the moon, and the moon tugging at the sea and giving it its rhythmic tides! Think of the hot steam condensing and boiling and bubbling in a terrific chasm twenty-seven miles deep, and how now

The gentle moon, that nothing doth but shine,
Pulls all the laboring surges of the world.

The tempests and tides must have been prodigious then, owing to the rapidity of the earth's rotation at that time and the nearness of the moon, and Sir Robert Ball has calculated that in early geological times the tides were over six hundred feet high, or twice as high as the cliffs of the Palisades rise from the Hudson.

Now the moon is 239,000 miles away; its volcanoes are extinct; it has forgotten how to spin; it moves with leisurely pace; and its tidal action is moderate. But we must look on it with respect and awe when we remember the story of its birth, and the fiery volcanic energy of its youth.

When the earth cooled down to a temperature of about 1200° C. it acquired a solid crust, and when the crust fell to a temperature of 370° C. steam began to condense out of the upper atmosphere.

What wild, fierce days these must have been — days of molten metal in red-hot caldrons, of lightning and thunder, of earthquakes and volcanoes. Réclus gives a vivid picture of these first days of the earth: "When the temperature was lowered sufficiently to enable them to pass from a gaseous to a liquid state, metals and other substances would fall down in a fiery rain on the terrestrial lava. Next the steam, confined entirely to the higher regions of the gaseous mass, would be condensed into an immense layer of clouds, incessantly furrowed by lightning. Drops of water, the beginning of the atmospheric ocean, would begin to fall down towards the ground, but only to volatilize on their way and again ascend. Finally, these little drops reached the surface of the terrestrial mass, the temperature of the water much exceeding 100 degrees, owing to the enormous pressure exercised by the heavy air of these ages; and the first pool, the rudiment of a great sea, was collected in some great fissure of the lava. This pool was constantly increased by fresh falls of water, and ultimately surrounded nearly the whole of the terrestrial crust with a liquid covering; but at the same time it brought with it fresh elements for the constitution of future continents.

The numerous substances which the water held in solution formed various combinations with the metals and solids of its bed; the currents and tempests which agitated it destroyed its shores only to form new ones; the sediment at the bottom of the water began the series of rock and strata which follow one another above the crust."

Such, then, is the probable history of the fiery, turbulent past of the earth. What do we know about its more prosaic present?

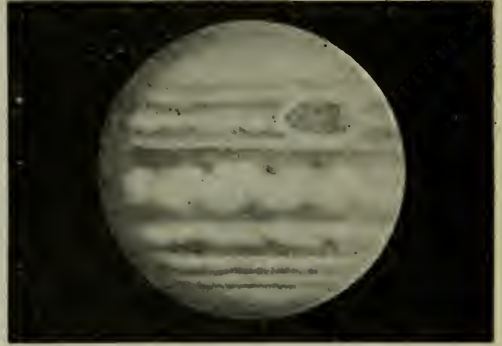
Astronomically and socially speaking, the earth is a member of the solar system. Spinning on its own polar axis as it goes, it journeys round the sun along with Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune, and it is placed quite appropriately between Venus and Mars. It is almost round, but not quite, for it flattens out a little at the poles, and bulges a little at its equator. According to the most accurate determination of the dimensions of the earth yet made, namely, that of the U. S. Coast and Geodetic Survey, completed by Hayford in 1909, the polar diameter of our globe is 7900 miles and its equatorial diameter 7927 miles. Its greatest circumference is nearly 25,000 miles. Its general substance is very dense, about twice as dense as granite and about five and a half times as dense as water, contrasting in this respect with the four outer planets, Jupiter, Saturn, Uranus, and Neptune, which are lighter than ebony.

Compared with other heavenly bodies, the earth is not large. It is larger than Mercury and Mars and Venus, but it is only a pea to a pumpkin compared with Jupiter, and only a midge to a mammoth compared with the sun.

Nor is the earth's pace anything exceptional. In 365 days it completes an orbit of over 580,000,000 miles, so that it averages 18 miles a second, which is to say that it flashes through space about fifty times as fast as a rifle bullet, and about a thousand times as fast as an express train. Not a bad pace, it may be said, but Venus and Mercury both go faster, and Arcturus goes nearly two hundred miles a second.

Not its size nor its speed, but its burden, is the boast of the earth. Whether it be

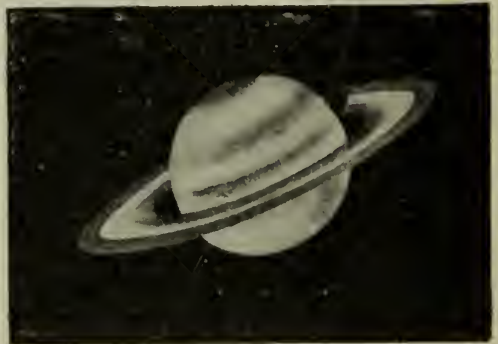
the only planet that is the chariot of living things we do not know, but the earth is probably the only planet that bears roses and trees and cabbages, beasts and birds and men. It is true that regular lines that are thought by some to be canals have been discerned on Mars; and both as-



A PICTURE OF A MOLTEN WORLD

One of earth's distant companions in her journey round the sun, Jupiter, is now in a molten state, as was the earth, which must have looked like this in the days before it formed its solid crust.

tronomers and novelists have been fain to imagine Martians; but however Mars may be — whether there be life on it or not — it is certain that the conditions there differ vastly from those we have on the earth and so the Martians, if there be any such, may differ much from men.



RINGS THAT GO ROUND A WORLD

Saturn, one of the earth's neighbors, pursues her journey through space inside mysterious rings that are probably made up of meteorites. Though more than seven hundred times as big as the earth, Saturn has a density less than that of water.

Round the sun speeds the earth; but the sun itself is not standing still; with all its retinue of planets it is rushing at a rate of ten or more miles a second towards the constellation of Lyra. Every year it is about three hundred million miles nearer: and who knows how long it has been rush-

ing towards its goal? Perhaps in a million years it will arrive there. But meantime our little solar system is isolated in space like a rock in the center of the Atlantic Ocean.

Such, then, are the astronomical characters — such, then, is the rapid, rushing everyday life — of the earth. Why the earth spins and revolves, why all the planets spin and revolve, we do not know, further than that in their orbital revolutions they obey the same laws of gravitation as a falling apple. The moon *falls* round the earth, the earth *falls* round the sun, an apple falls to the ground. But though we do not understand the force of gravity that causes the particular motions — that makes moons and apples fall, and pendulums swing, and bullets describe the curves called parabolas — we do know that it is this force that holds the universe together; we know that if it were stronger the earth would fall into the sun; we know that if it were weaker the earth would fly off at a tangent like a stone from a sling; and we know, too, that to the earth's inhabitants the earth's tremendous motions have momentous consequences. It is the rotation of the earth on its axis that gives us day and night, and trade winds, and all that these mean; it is the revolution of the earth round the sun that gives us our seasons, and all that they imply. Let us look at the motions of the earth a little more in detail, considering what they mean.

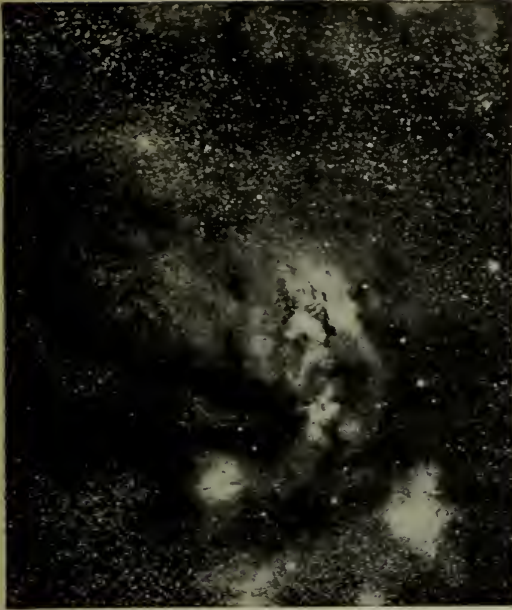
First, let us look at the earth's rotation on its own axis. The axis round which the earth revolves is a line passing between its two poles. Round this axis it rotates eastward, at such a pace that it turns completely round in twenty-four hours. This means that any point on the earth's surface at the equator rotates eastwards at the rate of 507 yards a second. But the

axis of rotation of the earth, while always keeping its direction in space unaltered, is not perpendicular to the plane of its revolution round the sun; it is tilted at an angle of twenty-three and a half degrees to this plane. The result of this is that as the earth progresses in its orbit around the sun each pole in turn points towards the sun, and then gradually points away from it again — as may be illustrated by moving a leaning pen round an ink-bottle, and considering the nib the South Pole and the other end the North Pole. The result of this movement is that at different positions in the earth's orbit the northern or southern hemisphere will have more sunlight at a particular time according to the direction of the tilt of its pole relatively to the sun. When the North Pole points most towards the sun, the northern polar regions will have perpetual daylight and a midnight sun and the northern hemisphere will enjoy its summer; while the South Pole and the southern hemisphere, leaning away from the sun, will be enduring their winter, with shorter daylight or without any daylight at all. These conditions gradually change and six months later are reversed, so that the South Pole will have for the time being continuous sunlight and the North Pole continuous night. Between these extremes there are two positions of the earth for which night and day will be equal to each other in both the northern and southern hemispheres, and so we get the "equal nights," which we call the spring and autumn equinoxes.

If there were no tilting of the axis of rotation of the earth, if it spun with its axis "straight up and down," so to speak, both poles and both hemispheres would always be equally exposed to the sun, and there would be no seasons, and day and



THE WORLD GOING ROUND, SHOWING HOW ONE PLACE TRAVELS 25,000 MILES IN A DAY AND NIGHT



A NEBULA THAT NO MAN HAS SEEN

The photographs illustrating this article were taken through the famous telescope at Yerkes Observatory, by Professor George W. Ritchey, except that on the left of this page. This nebula, taken by Professor Edward E. Barnard, can only be studied photographically, being too faint to be seen even through the telescope.



A NEBULA IMMERSED IN STREAMS OF STARS

night would be equal all over the world — twelve hours night, and twelve hours day.

Our seasons, then, and the varying proportions of day and night, and the necessary consequences of these things, are due to the tilting of the earth's axis of rotation. The tilt of the earth's axis of rotation is not quite steady and constant; it sways a little and describes a conical movement, a little like a wobbly spinning top, so that its poles make small circles and point in circular succession to different stars. It takes 25,800 years to sway round a circle. This swaying is due to the fact that the earth is not a perfect sphere but bulges somewhat at the equator and thus allows the sun and moon to exert on it a force that tends to change the direction of the axis of rotation.

Besides this conical motion there is a direct oscillation to and fro of the earth's axis of rotation, so that at times the earth spins more erect than at other times. The result, of course, is to alter the proportionate length of day and night at all seasons over most of the globe. When the axis is most tilted the polar regions enjoy about $8\frac{1}{2}$ days more sunshine.

Thus our earth spins and wobbles and nods on its journey through the heavens.

Now let us look at the second great motion of the earth — its revolution round the sun.

In its course round the sun the earth describes not a circle but an ellipse, and the sun is placed not at the center of the ellipse but at one of its foci. Accordingly the earth in its circuit approaches and recedes from the sun. At present at its nearest point it is 91,350,000 miles from the sun, and at its farthest point it is 94,450,000 miles away.

It is necessary to say *at present*, because the ellipse described by the earth is liable to be altered by the attraction of Venus and Jupiter, and at intervals of two or three hundred thousand years great eccentricities take place, so that the difference between the nearest and farthest points may become as much as 14,000,000 miles.

Summer and winter do not depend on the earth's distance from the sun, but on the tilting of the earth's axis. If the North Pole lean away from the sun, it will be winter in the northern hemisphere, whether the sun be near or far; and if it lean towards the sun, it will be summer in

the northern hemisphere, whether the sun be near or far. At present the North Pole is tilted towards the sun when the earth is farthest away, and so we in the northern hemisphere have summer when we are farthest from the sun; and the opposite relationship obtains in the southern hemisphere. But we must consider this question when we come to speak of climate; the main facts to be noted now are that the earth moves in a variable ellipse, and is tilted on its axis to a varying degree.

Such, then, is the earth as we now know it — an oblate spheroid of great density spinning rapidly on a tilted axis as it rushes at the rate of eighteen miles a second round the sun. Such, then, is the earth, wobbling a little as it spins, while its orbit becomes rather eccentric now and again owing to the attraction of Venus and Jupiter.

We have spoken of the motions of the earth in their relations to light and darkness, summer and winter, but it is too often forgotten that these motions may have vital significances — must, indeed, have vital significances — of which as yet we know but little. The terrific career of the planets through space must have very definite consequences. Think how the earth spins on its axis and flashes eighteen miles a second through the ether! It is certain that that motion must affect to some extent light, heat, and electricity, and perhaps also gravitation, and other forces that act upon the earth. Suppose it were possible for the earth to stand still, can any one believe that light and heat, and all the waves of ether proceeding from the sun, would not have consequences quite different? The motions of the earth, then, must be considered not only as the causes of night and day, summer and winter, and trade winds, but as also a factor in all the great world-forces which have cosmic relations.

Man, as we said at the beginning, is a pygmy compared with the world he inhabits; but let us never forget that, big though the world be compared with the creatures it carries, it is yet but a speck compared with the colossal masses with

which all space is strewn. The earth is less than one-millionth part of the size of the sun; yet the smallest nebulae we know are larger than the sun, and some of the larger nebulae confound imagination. "The earth," writes Sir Robert Ball, "sweeps around the sun in a mighty path, whose diameter is not less than 185,400,000 miles. Let us imagine a sphere so mighty that the circle would form just such a girdle round its equator, and let this gigantic globe be the measure wherewith to compare the bulk of the vast nebula of Orion. It can be demonstrated that a million of these mighty globes rolled into one would not equal the great nebula in bulk, though how much greater than this the nebula may really be we have no means of ascertaining." Yet the nebula of Orion is only a shred compared with the Milky Way!

And space is thronged with enormous masses of which earth is *one*, one of a host innumerable — millions and millions of shining suns, and millions and millions of burnt-out suns; for there are dark stars as well as shining ones, and it may be that the dark ones far outnumber those we can see.

We have merely glanced here at the general characters of the earth and its relation to the universe, but enough has been said to show the grandeur of the starry stage on which we mortals play our little parts. It rests upon us not merely to know, but to realize, these great facts — to realize that the earth is not the earth of our visual horizons, but a great globe whirling through space — a great globe with a fiery past, one in the brotherhood of innumerable suns and stars that throng the heavens. If we can realize this, life becomes a greater and diviner thing. Surely a nebula is large enough to burn up all the petty cares and fears of life.

Well may we think of the magnificent lines of the inspired poet —

"Where wast thou when I laid the foundations of the earth? Declare, if thou hast understanding. Who hath laid the measures thereof, if thou knowest? or who hath stretched the line upon it? Whereupon are the foundations thereof fastened? or who laid the corner-stone thereof, when the morning stars sang together and all the sons of God shouted for joy?"

THE GRANDEST OF THE SPIRAL NEBULAE



A WONDERFUL PHOTOGRAPH OF A NEBULA FROM WHICH NEW WORLDS MAY EMERGE

The nebula of Andromeda, filling space for millions of miles, is a huge area of incandescence such as the earth and our solar system are supposed to have been. From some such fiery cloud our earth is supposed to have evolved, and from this cloud itself may be now evolving new stars and solar systems.

THE VOYAGE INTO AN UNKNOWN LAND, WHICH ALL MUST MAKE ACROSS THE SEAS OF TIME



"WHERE LIES THE LAND TO WHICH THE SHIP WOULD GO? FAR, FAR AHEAD, IS ALL HER SEAMEN KNOW"

This beautiful painting of life's last journey is by Byam Shaw, and is called "Whither?"

THE MYSTERY OF MYSTERIES

All the World's a Stage and All the
Living Things the Author's Players

THE ADVENT AND SPREAD OF LIFE ON EARTH

FOR ages and ages the universal forces under the guidance of the Creator had been building a theater, and setting the stage for the play of Life—a drama which will reach its appointed end, when the idea is fulfilled of the Omnipotent Author, whose power and purpose are behind the timber of the stage, the line and pigment of the canvas, every atom and iota of the setting of the scenes. All the world's a stage, and all the living things the Author's players.

No image can do justice to the theme, but this of a drama has suggested itself again and again to great thinkers and poets since the dawn of recorded thought. And the more we study the being and becoming, the doing and the suffering of life as manifested by living things, the more do we perceive that the whole work of creation is not a matter of chance but an ordered, well-directed development toward some destined end, which they also serve who see it not at all. This, of which human dramatists and reformers themselves, along with other living things, are the creatures, can scarcely be less "a play with a purpose" than any of theirs.

The conditions of the beginning must be studied in a succeeding chapter; here it is necessary only to be assured that, notwithstanding the fantastic hypotheses of past times, the life which has appeared upon the earth is itself peculiar to the earth. That which was true in the beginning, is now, and ever shall be. Other forms of life may have appeared, and may yet appear, on other planets. On that we can do little more than speculate as yet. But terrestrial life is a part of Mother

Earth. Of life in all its forms, from microbe up to man, earth is the womb and the tomb. If life should attempt to establish itself without reference to the conditions imposed by the laws governing life on earth it must fail. This is true of the tree in the wood, and of the man on the street. Failure to recognize it is the constant tendency of civilization; the civilization which does recognize that the laws of life are the laws of all life, will be the first to endure and the last to survive.

When conditions upon the earth were such as to sustain life through the will of that same Power that called the earth itself into existence, living things came into being as an integral part of the plan and purpose of the Creator. Under what forms these first manifestations of life appeared upon earth, whether they appeared first in water, as some believe, or upon the land, whether they were similar to the lowest forms of living things known to us now, no living man knows. But, if we may judge at all by the consistent behavior of all the forms of life that we now know, life in its varied forms speedily took possession of this planet. Endowed by the Creator with original and inexhaustible powers, it developed new forms to suit an almost infinite variety of terrestrial circumstances. Today the earth literally teems with life wherever the "irreducible minimum" of conditions is complied with. So rapid and thorough is the penetration of new life whenever it obtains a new chance—as when the rabbit is introduced into Australia, or the microbe of plague into Manchuria or some European weed into American streams—that we may

reasonably suppose this teeming state of life to have been established with extreme speed after the first coming of life at all, and to have been the condition of our planet ever since.

The forms have been various indeed; the degree and what we may call the "intensity" of life may have varied, as when we compare the ox and the tiger, or almost any plant with almost any animal; but the extensiveness of life is of old standing, and nothing can resist it if the conditions of its nourishment be complied with.

Life cannot grow in the waterless desert, nor in carbolic acid, nor in an atmosphere of nitrogen — except for some microbes which can get oxygen to breathe by break-

man, whether it may not conquer other worlds as well.

This exception seems a real one, but life is not mocked, even by man. If man, in his unparalleled fashion, does not choose to multiply as he might, then lower forms of life, animal or vegetable, will utilize the space and the opportunities which he refuses, as, for instance, in the case of two recent immigrants into Australia, the white man and the rabbit, where the rabbits multiplied so rapidly that they threatened to drive the white man out of the country by eating up the crops upon which the man depended for his subsistence.

We here speak and think of life as one, despite the bewildering and staggering multiplicity and contrast of forms under which it is manifested — man himself, and the parasite that causes his hair to become thin, the grass growing under his feet, and the lark flying overhead. But all life is veritably one; the fundamental laws of life are the same for all forms of life and in this sense all living things may be said to be related. Job said that man is a worm, and modern science has shown that, like the worm, he develops from a single cell, a fertilized egg. If there were no microbes there would be no man, for the earth would be an uninhabitable charnel house without their ceaseless labors of putrefaction and fermentation, by which the earth is kept ever clean and sweet for new life. If there were no man, again, many recently discovered forms of microbes, which can live only inside his body, would not exist. Thus, though the struggle for life between the man and the microbes may not appear fraternal, it is inevitably fratricidal; struggle though they may, they are mutually dependent upon one another. Again, "all flesh is grass" in the profound sense that, but for the grass and its chemistry, there would be no food for animals, and therefore no flesh — which is true of human flesh as of bovine; of the meat-eater as of the vegetarian.

Living things may be animal or vegetable, large or small; they may flourish in the lowest and blackest depths of the ocean, miles below the surface, or upon the



CELLS OF LIFE

All life of whatever kind, animal or vegetable, is lived in cells, of which these two are types — from a potato.

ing up compounds containing it; yet, if given the conditions suitable for any life at all, all the life possible will avail itself of them. To this proposition, which has been wholly true until almost our own times, there appears to be a unique and staggering exception, wholly without any parallel in the animal or the vegetable world, furnished by those human communities whose members do not multiply, even though food and room be available. Apart from this exception, which involves the destiny of mankind as nearly as anything that can be named, it is and always has been universally true that life irresistible must go everywhere; and, indeed, having conquered the earth, begins to wonder, in the mind of its protagonist

dizziest crag, like the eagle or mountain-ash, but they all consist of cells, they must all breathe or die, feed or die. Prussic acid, chloroform, alcohol, carbolic acid, in sufficient concentration, will kill a whale or a microbe or an oak or a man; and each of these will equally die if atoms of the element carbon, or of nitrogen, or of oxygen, or of phosphorus, or of hydrogen, be omitted from its diet.

I write in a garden, and evidence of the variety and the unity of life is all around me — birds overhead, grass under foot, countless varieties of vegetable microbes and minute animal forms of life are in the soil, or there would be no grass. I am eating the fruit of a tree, and the seeds which I reject stand for the future perpetuation of life, which is the first and most constant desire of living nature, much more constant and profound, indeed, than the "law of self-preservation."

A small child plays upon the grass. The harsh, repeated cry of a blackbird in distress reminds me of its young, for which it fears, as I do for my little daughter, when she starts to eat an unripe apple,

which contains the seed of the tree beside me. I look round, and see the expected cat, the cause of the blackbird's distress. The cat has its own needs, for self and for its young, and they conflict with the blackbird's. I mark the marvelous quietness of the cat's approach, the breadth of the bony arches

which carry the muscles whereby it bites so strongly and surely, as the blackbird well knows, and I perceive that life, imperious, inexhaustible, patient and impatient,

frugal and lavish, protean and constant, is endeavoring to fulfil its inalienable purposes in all of us, from the soil under my feet to the brain whereby I am now earning my children's bread.



From Shackleton's *The Heart of the Antarctic*, J. B. Lippincott Co.

A WATER BEAR

Found in large numbers in the regions near the South Pole.

Well may Bergson declare that there is a profound and significant contrast between the course of what we call "inanimate matter," and the course of life. In the inorganic world the tendency is ever downwards, in a sense, towards the "dissipation of energy," as Lord Kelvin called it, towards the lowest level, as water falls towards the line of least resistance. Life, on the contrary, notwithstanding its obedience to the universal laws, is ever pressing onwards and upwards. Not for it is the line of least resistance — it may use that line, and does, but not for its own purposes, which are those of *most* resistance. Atoms disintegrate, even the glories of radium depend upon

its destruction and resolution into simpler, lower forms. But life creates, constructs, invents, fights, adapts, conquers, ascends, and is not satisfied.

This is what Bergson calls the *élan vital*,



From Shackleton's *The Heart of the Antarctic*, J. B. Lippincott Co.

LIFE IN THE SNOWS — THE ROTIFERS OF THE ANTARCTIC

These are the little creatures, invisible to the eye, which give the pink tint to the snow near the South Pole; they were photographed by the Shackleton expedition. Neither freezing nor heat near to boiling seems to kill them.

which we may, perhaps, most briefly translate as the "go" of life. There is nothing like it. It is marvelous in the sprouting seed; it is divine in the pioneer of thought; but, whether in the acorn or in a Newton, or a St. Francis, it is a manifestation and unique characteristic of what we call life. We

may be hard put to it to define the term, but there can be little doubt of what we speak, when it displays such deeds as these. No doctrine which splits the universe into

the living and the dead, no doctrine which denies the elemental laws of physics and chemistry is necessary in order that we should recognize life to be something which is real and separate, whether in grass or in man, though the atoms of the bodies of both were once in the soil and air, and will assuredly be so again. The grass and the man, nevertheless, are real and separate, and so, everywhere and always, is life.

Let us be quite sure that this life of which we speak is a very real and very *vital* thing. Science reading the records stored in the rocks, points to an earthly period when there was no life at all, and



From Shackleton's *Heart of the Antarctic*, J. B. Lippincott Co.
"WHEREVER MAN GOES, THERE LIFE HAS BEEN BEFORE HIM"

A penguin in the snows of the Antarctic.

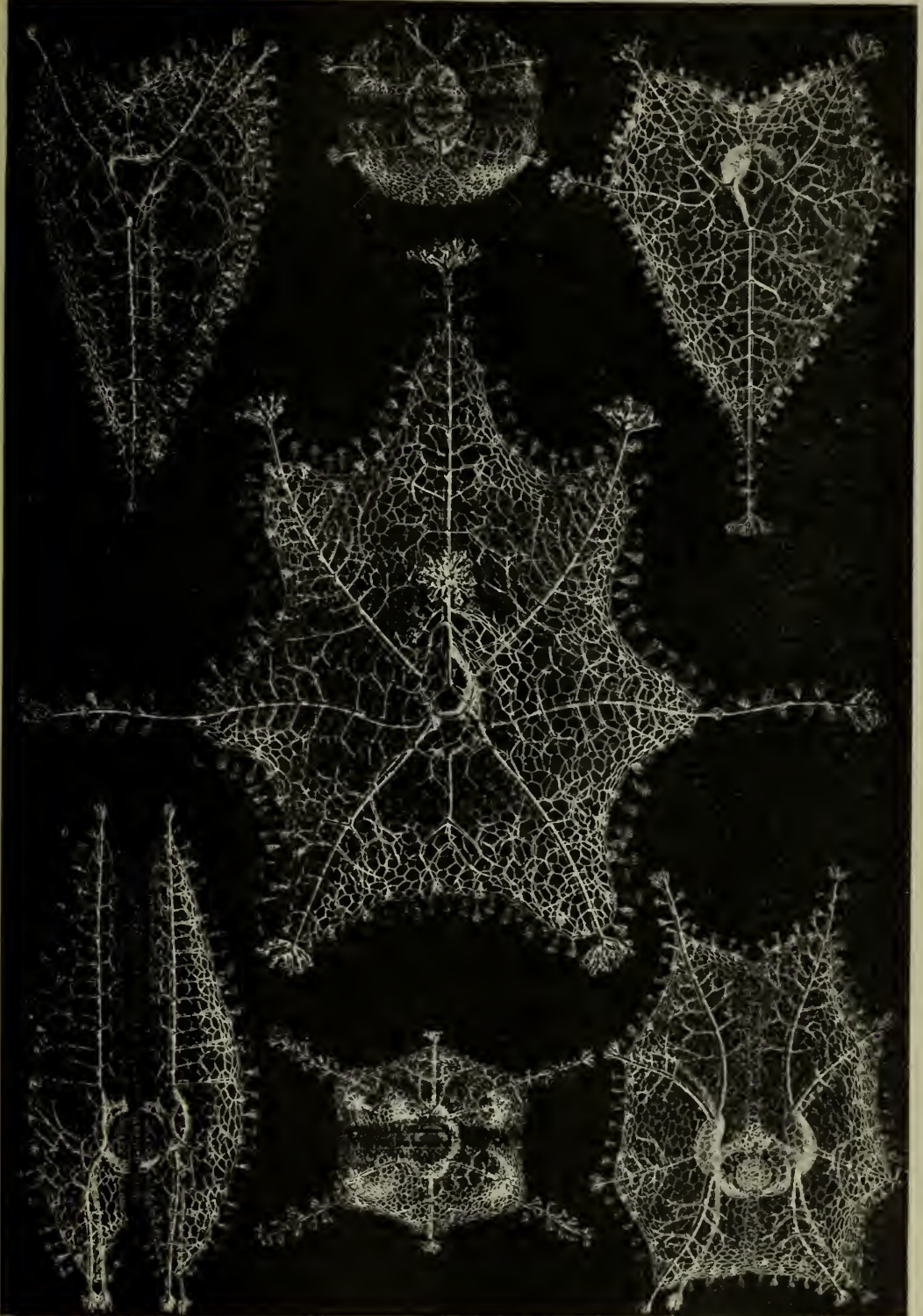
life now teems everywhere. It cannot do without certain conditions, among which a vital one is the need of water; but if these be granted its capacities are endless. The sea, and all waters not too salt, are crammed with life today. But water contains little oxygen, and life desires intensity. Since for that purpose, a richer supply of oxygen is needed, it has established itself in the air, though its primal need for water remains, and every air-breathing thing is within a short time of dying of thirst. The very bird of the air is a manifestation of life living in water — which, indeed, constitutes some three-fourths of its bodily substance.

More widely still considered, life presents the spectacle of marching down two great avenues, each of which, in its way, makes for "more life and fuller." Except for some of the lowest organisms, whose classification is very uncertain, science separates all living things into plants and animals. Both are equally alive, both are made of cells filled with living protoplasm, both live their lives in water; and without plants there would be no animals. But their vital methods are very different. The plant is content to be just a vegetable, to stay where it finds itself, and feed and breathe on what the movements of soil and wind and water bring to it. The animal is for a shorter and intenser life; and since this involves a special type of food, not everywhere to be found, the animal must go in search of what it needs. These two contrary forms of life are found everywhere — at every level in the sea, in every part of the land, high on the sides of mountains, and the very air is inhabited by birds and insects and the flying seeds of plants, seeking a spot for the life of the new generation.

"In two main shapes," says Stevenson, "this eruption covers the countenance of the earth, the animal and the vegetable, one in some degree the inversion of the other, the second rooted to the spot; the first coming detached out of its natal mud, and scurrying abroad with the myriad feet of insects, or towering into the heavens on the wings of a bird — a thing so inconceivable that, if it be well considered, the heart stops. Meanwhile our rotary island, loaded with predatory life, and more drenched with blood, both animal and vegetable, than ever mutinied ship, scuds through space with unimaginable speed, and turns alternate cheeks to the reverberation of a blazing world, ninety million miles away."

There are more than 130,000 kinds of beetles alone, millions of species of animals and plants, and more are constantly coming into existence as life discovers new possibilities. The total number of living individuals is utterly inconceivable if we consider the present only, and immeasurably more so if we include

EIGHT MILLION HOMES IN AN INCH



In these lovely lace-work shells exist tiny radiolarians so small that eight millions can live together in a cubic inch. Thousands of species, marvelously varied in form, are found in the Pacific Ocean, and countless myriads die every moment, falling to the ocean bed. The flinty shells are made by the creatures themselves, and through their openings the jelly-like bodies put out feelers to seize food.

the past. Out of apparent nothingness and night came this irresistible, incomparable thing, of which it may well be that we see the merest beginning.

All things move — rocks and crystals grow; living things move and grow, too. Vital growth is achieved by the intake into the living substance of materials which it endows with life, or uses for the purposes of life. All individual bodies, whether a moss or a microbe or a man, are destined to die — as individuals. But they are endowed with the powers of reproduction or parenthood, which is another of the unique and inimitable marks of life. And living things may be moved, as other things may be, but they are also capable of movements which, though ever obedient to the laws of physics, are unique in their purpose and their originality. Water runs downhill, but the heart pumps the blood uphill and down, wherever it is wanted. Light exercises a repelling force in all directions and upon everything material, but the living moth flies towards it. An avalanche, nay, the earth itself, moves as it is moved, taking the easiest course, but a soldier or a mother, nay, an old male baboon, will climb uphill to certain death, will venture among the deadliest foes, to save their young. There is nothing that life will not dare for life.

From the living to the not-living perhaps no breach in nature's continuity

It is true that we may later learn how closely some of the attributes of life may be displayed in its absence. The study of ferments points to the possibility that the gap between the living and the not-living is no breach in nature's continuity, did we but know. All this we must study, but not without realizing that the characteristics of life are not thereby diminished or denied, any more than the plays of Shakespeare are discredited because he was once a baby. Things are what they are, no matter how completely we can trace their origin and connections. Fools, it is true, may marvel at them less, but the wise will marvel more. The student of life, who must necessarily be the admirer of life, need not suppose that the lark's

song and flight, or the splendor of the rose, would be less than they are, even supposing that man should succeed in manufacturing larks or roses in the laboratory tomorrow.

The great purpose of all life is the making of more life

As we witness and wonder, one question forces itself more and more upon us. The push, the "go," the tireless thrust, the inexhaustible resource of life — for what are they? Is life as such, in whatever form, an end in itself, or is it a means to an end?

These may be questions which we cannot answer, but it is better to have asked in vain than never to have asked at all, and the answers will yet be found.

Certainly the proximate purposes of life can be discerned. In Tennyson's phrase, it is "more life and fuller" that all living things want. Whether intensively or extensively, life is always asking for more. Its courage and initiative and resource, its incapacity to know when it is beaten, and its unfailing resurrections, these are definitely engaged in seeking the constant end of all forms of life — more life and fuller. In general the proposition may be laid down that the method of "extensive culture" always tends to be succeeded by that of "intensive culture" — to borrow terms from the farmer. Life begins by taking hold everywhere, from the mountain side to the depths of the ocean, over hill, over dale. Every species is a champion of life. Species may fight and eat each other in an apparently mad and wasteful fashion, but one and all are for the common end — more life.

Thus there gradually emerges a greater intensity in the areas already covered — as a first stage, so to speak — by life of lower intensity. The animal world supervenes upon the vegetable. Active fish follow after the seaweed, birds surpass insects, restless, quick-eyed carnivores tend to supersede the lower mammalian forms which munch grass all the day, until at last there appears the most intense and restless and insatiable and hungry and inventive of all living beings, man himself,

who is the master and the terror of all other beings — except, for a few more years, certain parasites — and who alone, of all living forms, increases in numbers. He leads the "fuller" life indeed, and as he conquers the continents he realizes the poet's phrase, making more life as well as fuller. And even in this dominant species the conquest and the future are always to the most active, the most intense — those who lead the fullest life.

We see the making of more life to be the immediate purpose of all life, and yet we are everywhere faced with the facts of death and murder and struggle and disease and starvation. If the young of the bird are to be fed, many insects must die; if man is to have bread, countless millions

which we find to be a general fact of the living world, and one of the most widespread and constant forms of the struggle for existence. Every new form of life is a chance for some other form of life to employ for its purposes, and thus the development of new forms leads to the corresponding development of new forms of parasites.

Practically the whole of disease thus takes an entirely new form in our mind's eye. It is one phase of the development of life, part of the struggle for existence. An attack of pneumonia is simply the rapid multiplication, in suitable conditions of temperature and food supply, of a particular form of simple plant which takes the opportunity of multiplying, as every living thing would do in similar circum-



FOR MILLIONS OF YEARS LIFE HAS MANIFESTED ITSELF IN THINGS OF ALL SORTS AND SHAPES
These pictures show three strange forms of life — (1) the short-headed frog of East Africa, (2) the "seaweed-like sea-horse" found in Australian waters, (3) an octopus like an umbrella, found in the Atlantic and Pacific Oceans.

of young wheat-embryos must be sacrificed; the big fishes eat the little fishes, and these the lesser still. This "struggle for life," or "struggle for existence," is one of the great facts of the living world; and only in the nineteenth century did men come to see that it could be interpreted as serving the purpose of life, even through this incessant spectacle of murder and death.

More astonishing still, while Darwin was explaining to us the struggle for existence, Pasteur showed that by far the greater part of all our diseases are due to nothing else than a struggle for existence between humble forms of life — mostly vegetable — and our own. In fact, one of the modes by which life seeks to extend itself is the paradoxical mode of parasitism,

stances. It is now life against life; incomparable man, battling with his chemical weapons against those of the parasitic vegetable which has found him a suitable home for itself and its progeny.

While some impartial point of view can be imagined from which the issue of this contest would be a matter of no concern, yet it is clear to us that the life of the man is high, and that of the parasite is low. Further, we are entitled to discover in all parasitism whatever, whether it affects us directly or not, a form of degeneration. In this struggle, therefore, our sympathies are with man and against the parasite; and parasites in general, though themselves alive and fighting for their lives, may be looked upon as the enemies of life, since they are degenerate, and their lives

lead to nothing but the destruction of higher living forms.

Thus it will be necessary for us to study the great world-processes of disease from this vital point of view, and to review the amazing fashion in which the highest form of life, which we call "man," is establishing its hold upon the earth, and learning to exterminate those lower forms which are the only living creatures that have not yet come completely under his sway.

The profound truth of science spoken by the greatest of Teachers

In this, as in so many other respects, man demonstrates himself to be a part of living nature, but the part which displays the characteristics of life in their most marked form. There is no other key to the behavior, the structure, the living and the dying, the selfishness and the unselfishness of living things but this: they are made to magnify and amplify life, directly or indirectly, in their own persons or in those of their descendants; and that which is true of all other living forms, in their lowest as well as their highest manifestations, is true also of man, and of man in all his aspects. Thus from the standpoint of the science of life no deeper or profounder words were ever spoken than those in which the greatest of Teachers said: "I am come that ye might have life, and that ye might have it more abundantly."

The answer which is so clearly given by the unanimous voice of living nature, from the lowest to the highest, and to which every attribute and character of every living thing, and even of death, bears witness, is only a proximate answer. More life and fuller is the purpose of all life; but is that all in all?

Are we really to regard the presence and maintenance of life — any kind of life — as an end in itself?

Though much is to be said for that view, it does not satisfy us. Indeed, life is never satisfied; its motto is ever "Excelsior," and we, who are now in the van, and who climb as all our predecessors have done, want to know the goal towards which we

climb. The man with an inquiring turn of mind sees that life ascends; he has observed the historical fact and progress. Once there were no brains upon the earth — once there was no motherhood. Reason and love have come out of the struggle; and they struggle still. Surely there must be some "far-off divine event to which the whole creation moves." Or is it rather that the Author is an artist who makes wonderful and lovely things, ever excelling Himself, and practicing the doctrine of "art for art's sake" as if to say the rose will die, but till then it is a rose, and beauty needs no further warrant for its existence?

Few there will be to content themselves with such an explanation. If, indeed, the history of the living world be a work of art, we cannot admit that it is finished. Plainly it is not finished, as witness the struggle and striving of the life of man. The warnings of the astronomers suggest that the story must come to an end some day. What end, then? And what of the countless millions who have lived and died without knowing or even imagining it?

It were wiser to be humble and silent, rather than essay answers to such questions as these. At times we may feel as Macbeth did when all was lost:

Tomorrow, tomorrow, and tomorrow
Creeps in its petty pace from day to day,
To the last syllable of recorded time,
And all our yesterdays have lighted fools
The way to dusty death. Out, out, brief candle!
Life's but a walking shadow, a poor player
That struts and frets his hour upon the stage,
And then is heard no more. It is a tale
Told by an idiot, full of sound and fury
Signifying nothing!

But faith and hope and courage and imagination are attributes of life, as we display and feel it; they have their warrant as eyes and hands have; and in virtue of them we may say with Tennyson:

At first, this earth, a stage so gloomed with woe,
You all but sicken at the shifting scenes.
And yet be patient. Our playwright may show
In some fifth act what this wild drama means.

WHAT THE SOIL IS MADE OF

The Composition of the Earth beneath Our Feet and Its Part in the Support of Plant Life

THE THINGS THAT MAKE THE EARTH FERTILE

MOST people consider the soil as an inert mass, having little or no relationship to plants except as a convenient means of mechanical support. They little realize how much the soil contributes to plant growth and that without the specific attributes and properties pos-

As a matter of fact the soil is not lifeless but is teeming with many forms of living matter. To be sure, the life forms are very minute, but this is made up for by their immense numbers. The individuals representing life underfoot exceed many, many times those above ground. They make up



From Yeaw's *Market Gardening*, John Wiley and Son

A SUCCESSFUL GARDEN

The production of abundant crops is both an art and a science upon which the future of mankind depends.

sessed by the soil no crop could be grown at all. Until recently few understood the chief causes of fertility and how productivity might be most economically increased. A clod of earth has so long been considered as a lifeless thing that the term is almost proverbial.

a world of their own, which rivals ours in wonder and importance. Most common of the forms are the soil bacteria or germs, which are present to the number of many hundreds of millions in every pound of normal soil. These germs influence the materials out of which the soil is formed and by

INCLUDING THE SCIENCES OF AGRICULTURE, BOTANY AND BACTERIOLOGY

the aid of physical changes and chemical actions make the soil a fit medium for the growth of crops. Thus the life below really supports directly and indirectly the life above.

Although the soil has not the fascination and interest possessed by some objects of nature study, no one can doubt its importance. On a proper understanding of the soil in relation to the plant depends successful agriculture, which after all is the basis of our national prosperity. Such a study, since it has to do with the all-important questions of food production, should receive some consideration, however small, in the education of all. The farmer, the gardener, and the fruit grower need much specific information. The banker, the merchant, and the manufacturer should know at least enough so that they may best encourage the economic production of food. The relation of the soil and the plant as regards the fruitfulness of the earth has become a question of national and world-wide consideration and merits very careful study.

Composition of the soil

Broadly speaking, every soil is made up of two very common materials, rock fragments and organic matter. The rocks usually found are our very common ones like granite and limestone, but they have through untold ages become ground up into very fine pieces. Some of these pieces are too small to be seen even under a microscope which magnifies many times. The organic matter is simply plant tissue which has decayed, the remains becoming mixed with the minute rock grains. This mix-

ture is usually so intimate that it is impossible to pick the soil to pieces and divide it into its two main constituents.

What the plant needs

The ordinary plant needs certain conditions for normal growth. Two of these are readily apparent, foothold and food. Besides these there are necessary air, heat, light, and water. Without these six conditions plants will not grow and consequently no food can be produced. While the soil does not furnish all of them, it is

interesting to know which ones are dependent on the soil.

It is evident that the soil supplies the foothold for plants. As it is possible for roots to penetrate and ramify through the soft soil mass, the plant can maintain itself upright despite the forces of gravity and of wind. When it is realized that the spread of tree roots equals that of the tops, the significance of support becomes apparent.

All life needs oxygen, which is an important part of our air. This air is almost as necessary for the roots of plants as

for the tops. Therefore, as the soil must allow the circulation of air to the roots, the supplying of this necessary factor of plant growth becomes a function at least in part of the soil. Also a certain range of temperature must be maintained for good plant growth. This heat relation concerns not only the air around the tops of the plant but the soil and air around the roots as well. The soil therefore supplies the plant with part of the heat necessary for the normal functions of growth. There is one factor of plant development that the soil has no part in



From *Soil Sense*, The Dunham Co., Berea, Ohio

The soil presents a foothold for plants and at the same time it supplies the feeding rootlets with water and mineral food. The carbon found so abundantly in plant tissue comes from the carbon dioxide of the air.

supplying. This is light. The light which is so essential for crop growth comes directly from the sun and falls on both soil and crop alike.

The water which the plant takes up through its roots comes almost wholly from the soil, the latter receiving it as rain. As this water circulates through the soil, in and out among the grains of rock and fragments of decayed plant tissue, it gathers up food, which is supplied to the plant through its rootlets. The water of the soil serves, therefore, not only as a food and regulator to the plant but as a carrier of nutrients as well.

Plant food elements

It must not be inferred from the preceding, however, that the plant obtains all its food from the soil. In fact, it receives but a small proportion from the earth, the major part coming from the air and from water. The things that must come from the air, from the water, and from the soil are so absolutely necessary that they are spoken of as "plant food elements." They number ten in all, and all must be present or the plant cannot grow. What a complicated process when growth depends upon the absolute coöperation of ten elements, the absence of one blocking the use of all!

While these elements are combined in the soil and water to make various compounds and are changed to other compounds when they are taken up by the plant, we will speak of them just as if they really existed in an elementary state. They may be listed as follows:

From air and water

carbon
hydrogen
oxygen

From the soil itself

nitrogen
phosphorus
potassium
calcium
magnesium
iron
sulphur

It is interesting to note here that the elements which the plant takes from the air and water are the ones largely lost when the plant is burned. When we think how

large and bulky a pile of leaves or of brush is and how little remains as ashes after burning, we can realize the relative proportions of the food which comes from the soil and from other sources respectively.

The carbon which a plant contains becomes apparent when a stick is charred in the fire. This carbon has existed in the air as carbonic acid gas (carbon dioxide), and was taken up by the plant. Oxygen, making up about twenty per cent of the air, is also taken up very largely in this direct way. The hydrogen comes mostly from water, which is a compound of the two gases, hydrogen and oxygen.



From Lyon and Fippin's *Principles of Soil Management*, Macmillan Co.

The small quantities of available plant food in most soils make an intimate contact between the soil particles and the rootlets most essential. The particles of soil are in some cases almost enclosed by the roots.

Most of the nitrogen which the plant uses is carried by the organic matter of the soil. The availability of this nitrogen depends very largely upon the bacteria already spoken of as inhabiting another world beneath our feet. Should these germs refuse to work the crops could obtain no nitrogen and would thus be unable to grow, even though all of the other elements were present in abundance.

The remaining six elements are often termed the "mineral" portions of the plant food. They come entirely from the soil, being held there as various compounds in the rock fragments. Some of them combine with the nitrogen, making the plant food of the soil a very complicated material indeed.

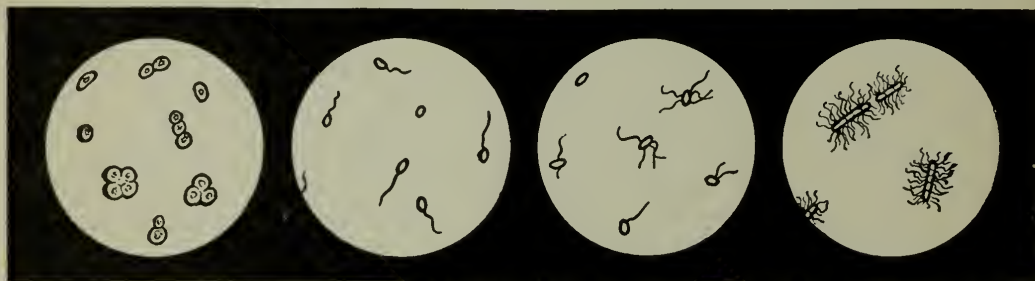
Primary plant food elements

While all of these ten elements must be available in order that the plant may grow normally, most of them are so abundant and so easily obtained that little attention need be given them in the study of the productive capacity of a soil. Three of them, however, are likely to be lacking or insufficient, and they are called, therefore, the "primary elements." They are nitrogen, phosphorus, and potassium, and should be thought of as the elements necessarily carried by fertilizers. When they are lacking the growth of the crop is hindered to the extent of their deficiency. They are what may be termed a "limiting factor" in crop growth. One of the worries of a farmer or gardener is: "Does my soil need a fertilizer and should this fertilizer

Available plant food

Food may be a limiting factor for plant growth in two ways. One, the actual absence of food from the soil, has already been mentioned. Just as serious a condition is attained when food is unavailable even though it be present in the soil in large quantity. Food must be in solution in the water which is circulating in the soil before it can be carried to the absorbing surfaces of the plant rootlets. If the compounds containing potassium, for example, refuse to go into solution, the potassium is of as little use to the plant as though it were not in the soil at all. In other words, it is locked up by its chemical combination and is unavailable.

Plant food problems, therefore, resolve themselves into this double question:



From Lyon and Fippin's *Principles of Soil Management*, Macmillan Co.

The availability of nitrogen, phosphorus, potassium, and other food elements to plants is determined to a large degree by the action of soil bacteria. The activities of the many different forms are varied and usually extremely complex. The life in the soil thus directly and indirectly supports the life above.

carry one or all of these elements?" The principles of fertilizer practice, therefore, hinge on these three elements — nitrogen, phosphorus, and potassium.

It must not be inferred that plant food is the only limiting factor for crop production. Many other conditions may come in and check plant growth even if food is very abundant. Suppose the soil is too hard and lumpy for proper root penetration; or suppose the ground is too wet, or too dry, or is acid; or suppose it harbors a plant disease. You see that while food is so necessary, its lack is not the only thing that may keep your garden from doing as well as you might expect. These examples illustrate the many phases which must be studied regarding the relation of soil and plant. Such intricate relationships make necessary a clear understanding of the soil as well as of the crop.

"Is food lacking or is it unavailable?" Questions of fertility grow more and more complex the further we inquire into them. If we are to supply food we must know what fertilizers to apply, their proportionate mixture, and their amount. If food is merely locked up, we must have the key or keys which will liberate the supply. These keys are represented by the physical condition of the soil, its chemical reaction, and its germ content and activity. The means of turning these keys are found in plowing, draining, manuring, and liming the soil. In other words, good practices of farming and gardening will turn the keys and unlock the treasures of the soil.

Abundance of plant food

The fact that food may be lacking in a soil suggests that the amount ordinarily present may often be low. As a matter of

fact, the soil is made up principally of inert matter which can never be used as a food and which only serves as a make-weight material. Quartz sand is a typical example of such compounds.

As nitrogen, phosphorus, and potassium are the only food elements likely to be limiting factors, we are interested in their amounts. Do not be surprised at their minute quantities! Nitrogen in a normal soil usually does not exceed two-tenths of one per cent, and phosphorus is even less, being on the average about five-hundredths of one per cent of the soil weight. Potassium, however, is much more abundant, making up from one to two per cent of the soil. Nitrogen and phosphorus must often

their composition, and from what we already know this must have a bearing on the fertility of the soil which has been made from the rocks by the grinding and pulverizing action of the weather.

A moment's thought will give us a clue to the identity of the rocks that probably make up our soils. It is evident, as soils are universally present, that the most common rocks must have been broken down to make them. Common everyday rocks would then appear in our list of soil formers, such as limestone, sandstone, granite, marble, slate, and shale. It is no wonder that the soil is such a common everyday affair. It is made of common everyday things!



From Merrill's *Rocks, Rockweathering and Soils*, Macmillan Co.

The minerals present in granite (left) and sandstone (right) become apparent under a microscope. When such rocks break up and become mixed with organic matter, these mineral fragments become the weathered and irregular particles of the resultant soil.

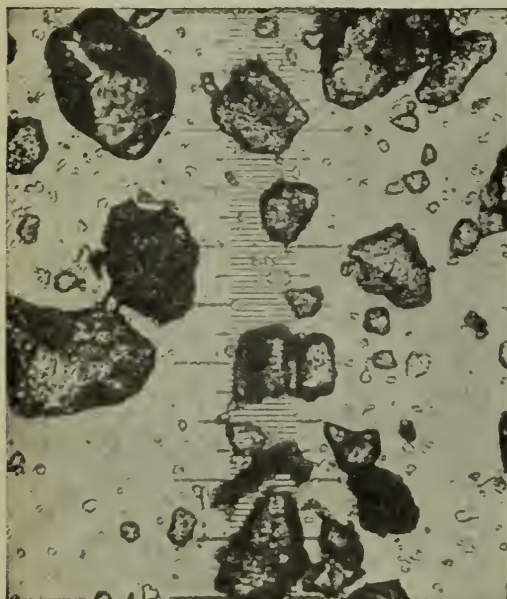
be added as commercial fertilizers because they may be actually absent; and potassium, although abundantly present, may have to be added because that which is in the soil may be unavailable. Is it little wonder that men are urging the conservation of our soil resources, especially of nitrogen and phosphorus! This is necessary not only for ourselves but for the generations that are to come after us.

Rocks and minerals that make up the soil

It is not enough to say the soil is made up in part of rocks and in part of organic matter. We must go still farther and inquire as to the kinds of rock and even what the rocks are made of. Rocks differ in

As a rock is made up of minerals we can go one step farther and inquire as to some of the minerals present, not all, by any means, but a few of the most common. Quartz, or sand, is probably the most noticeable, and this in sandy soil may make up the bulk of the minerals present. It loosens up the soil and makes it light and loamy. Calcite, or calcium carbonate, is another mineral present. It is important, as it carries lime. Apatite and orthoclase are complex minerals carrying phosphorus and potassium in complex or, if you please, locked-up conditions. Hematite and limonite carry iron and give the striking red and yellow colors so characteristic of many soils found in the southern part of the United States.

Many more minerals are present in the soil in small amounts, but those already named will be sufficient to illustrate the mineral composition of the soil. It is to be remembered that the mineral elements of plant food (potassium, phosphorus, sulphur, calcium, magnesium, and iron) are carried in these compounds. Sometimes the constitution is simple and the elements are readily available as plant food. Sometimes the minerals are very complex and insoluble and the plant food elements are unavailable until the right condition or complex of conditions is found that will unlock them.



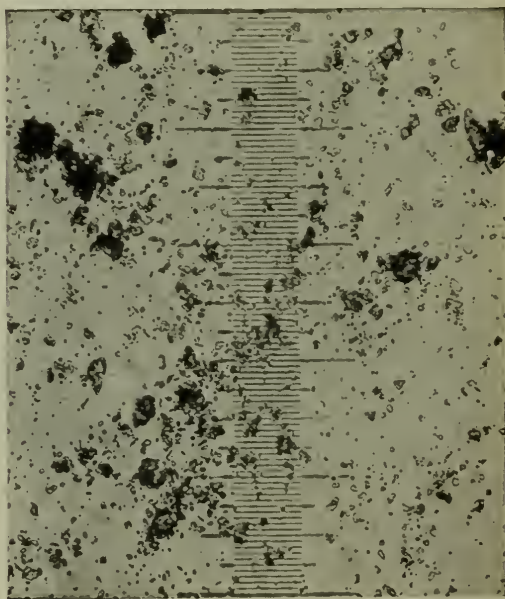
The particles of a soil vary as to shape, size, and composition and give it distinctive characters. The larger particles are "sand" which makes the soil loose and open. The very small fragments are called "clay" and make the soil compact and often difficult to cultivate when present in large amount.

The soil particles

It is not to be supposed that the mineral particles which make up the larger proportion of the soil are all of the same size nor are they all round in shape. The sizes range from stone or large gravel that may be readily seen and handled individually, to particles almost infinitely small, too small to be seen under the microscope. They are named according to size. Stone and gravel are the largest, followed by various grades of sand and lastly by silt and clay particles. The smallest sized sand particle can barely be seen with the naked eye. The largest silt particle can-

not be seen without the aid of a microscope. The shape of soil particles is variable. Some few may be round. The majority, however, are angular and irregular. Some are mere shreds of the various minerals.

As might be expected, the size and composition of the soil particles have a great deal to do with the fitness of the soil for plant growth. The size of the particles and their arrangement govern the movement of heat, air, and water through the soil. The penetration of the roots is influenced thereby. The minerals present control the food which will become available for the plant. These illustrations are



sufficient at this point to emphasize the importance of the soil particles to the question of productiveness.

One of the great differences between a soil and a mass of ground-up rock lies in its organic matter, existing as it does in such an intimate relationship to the mineral portion. This organic matter is necessary that the earth be fertile. It makes the soil loamy, it allows air to circulate, it holds water, and it stimulates the activity of the bacteria, already voted so important to plant growth. Besides, it carries the primary element, nitrogen, so vital to all forms of plant and animal life.



From Fletcher's *Soils*, Doubleday, Page and Co.

THE THREE INGREDIENTS OF A SOIL

Besides clay (right) and sand (center) a soil should contain organic matter (left). These ingredients when present in proper proportion will give a loamy, friable soil, easy to cultivate and wonderfully fertile.

Organic matter of the soil

The source of most organic matter is plant tissue, which has accumulated from plants growing on the soil. Such material has become gradually mixed with the surface soil in the ages past. This is nature's process. Man may add organic matter in various ways, as by applying farm manure or by plowing under green crops. In whatever way the plant material is added the results are the same. It decays and blackens; it becomes finer and finer as it intimately associates itself with the soil particles; it changes in composition until the soil as we see it today is produced. This process of decay and of simplification, which ultimately causes the nitro-

gen carried to be yielded to the plant, is a bacterial one. Were the soil germs to refuse to work, plants would soon be unable to grow on the earth.

While the organic matter of a soil is so vital and so important, its amount is usually not large as compared with the percentage of mineral material. Four or five per cent of organic matter is a moderate quantity for a normal soil, while ten is excessive. This is, of course, excepting peat and muck soils, which are largely organic in nature.

The ideal soil

The ideal soil will not be one in which the particles are all large, neither will it be one where the particles are all small. A



From Fletcher's *Soils*, Doubleday, Page and Co.

SURFACE SOIL AND SUBSOIL

The surface soil through which the plant roots ramify is markedly higher in organic matter than the subsoil beneath, as can readily be seen. The nitrogen of the soil is carried by the organic matter.



From *Soil Sense*, The Dunham Co.

A SOIL IN GOOD CONDITION

Proper tillage and moisture condition are just as important in crop production as sufficient plant food. The maintenance of a good physical state is necessary in successful soil management.

happy mixture of all sizes is most likely to give a loose, open, friable structure. Such a mixture carrying plenty of well-decayed organic matter should afford the physical condition, the chemical composition, and the bacterial activity for maxi-

mum crops. The big particles afford a few large pore spaces and give good drainage and good air movement. The small particles cluster together in crumbs. They retain water and afford food. The organic matter leavens the whole mass and promotes bacterial action. It pushes the particles apart and yet binds them loosely together. It retains water and yet stimulates drainage and aëration. All these conditions unite in bettering the factors so necessary for plant growth. Such a soil of necessity has a high crop-producing power and is generally spoken of as a "loam." It is a rather fortunate coincident that most of the soils of the United States are loams of some type.

The soil and the plant

Observed from the standpoint of plant growth the soil is purely a material useful for crop production. Its physical condition, its composition, its internal life, and its changes become of vital importance. As already shown, the plant depends on the soil for more than a mere foothold. Most of the factors necessary for crop-growth are supplied wholly or in part by the soil. It is evident that a proper understanding of the soil will allow the farmers and gardeners not only to increase their output but to maintain and improve the fertility of our greatest national resource — the soil.



THE FERTILITY OF THE SOIL IS THE FIRST FACTOR IN THE SUCCESSFUL DEVELOPMENT OF A GARDEN

RIVALS FOR THE MASTERY

The Early Days of the World When
Man and Mastodon Met in Combat

WHAT THE FIRST ANIMALS WERE LIKE

MAN is lord of the animal world, its highest consummation; but what if man had never been created? Would nature have then evolved the autocrat of the earth? How would she have fashioned him, how arrayed him? With what powers would she have invested him?

It is hard for the lay mind to conceive of a world without a man, though it was such a picture, indeed, that the earth presented until organic life had been millions of years established. We dimly realize that time and space have neither beginning nor end; and human life seems at first sight also to belong to the infinities. The idea of man's late beginning seems too unreal, perhaps, for our acceptance. The picture of man as semi-human, a beast warring with other beasts for bare existence, comes to our minds as preposterous and grotesque.

But the fact remains that man is a mammal, the most modern of the animals, and has come to his present stage of mental superiority comparatively recently. In his embryonic development, he still recapitulates in large measure the stages through which the life on the globe has passed. Beginning with the single egg and passing through stages that are comparable with the lowly forms of life that are still found in the sea, he passes rapidly over stages that represent millions of years in the development of life on the globe, until he is finally recognizable as a vertebrate and then a mammal. The great development of his thinking brain, however, finds no counterpart in the history of life on the earth and because of it, we must believe that he was given mastery of the world.

We need not attempt to catalogue the early stages of the story of organic life. The record is lamentably incomplete, though some of the early forms have left their records in the shape of cliffs and mountain ranges built up solely of their skeletons. Great cities flourish on foundations built up of the minute shells which sank in unnumbered millions to the bottom of oceans which have long since changed their beds. With the vertebrates came a scorpion, among the first of known land animals. It was a great day in the history of the world when he first crept out of the waters.

Then our record takes a flying leap and clears millions of years at a bound, for among the next notable finds revealed to us is the armored fish. We have as yet no record of the intervening forms which must have led up to this specialized animal, but here the story of evolution is first graphically impressed. The great battle for existence, for betterment, for conquest, had begun. The making of man was still far off in the ages of time, but the fight, beginning with the inception of life and continued ever since, was in full swing. The fishes had armed themselves; they had laid on plates of mail and cultivated formidable sharp-gripping teeth. "Eat or be eaten" was the law. And the scorpion, wearying of the conditions, had betaken himself with his sting to the land, though leaving his family abundantly represented in the waters.

In the same line of ascent with these creatures came the insects and spider-like animals. And here was another significant era in world-history. In the insects

an order was here brought into existence destined to have immense influence upon practically every other form of life. Forth came parasites to prey upon other animal forms, to play their part in the vegetable world, and prepare a way for man. With the insects came a higher intelligence than had yet been created. Improvement was proceeding.

The coming of the insects at a time when the other life forms were seemingly so different from them has been a puzzle to many a student, but readers familiar with Sir John Lubbock's valuable studies find there a good anchorage. There seems at first to be little in common between the stag-beetle, the dragon-fly, the moth, the bee, the ant, the gnat, the grass-hopper, and other less familiar types all differing in size, in form, in color, in habits, and in modes of life. Yet the researches of entomologists

have proved not only that such insects, while differing greatly in details, are constructed on a common plan, but also that other groups can be shown to be fundamentally similar. While the mature forms differ greatly, the embryo forms are so similar as to be clearly reducible to one common form.

Millions of years were passing, and new forms continued to appear. Special types

arose and vanished, unable to tolerate the altered conditions which successive ages imposed. Bulk and strength were the dominant features of the newer developments. Crust-clad animals of colossal size arose, and subsided into the mud which has become rocks. Vast cuttlefish thronged the seas, and many a legion of molluscs. Then came the amphibians, water-born animals which go ashore to live, and the way was clear for the reptiles.

At this point the race for the mastery of the world became a thing of stern reality. Not consciously, of course, but by their very existence the reptiles sought supremacy. And they obtained it. The world was at their mercy, and this fair earth had lizards and other reptilian monsters for its lords.

In the sea were the huge fish-lizards, with paddles for limbs and bodies like whales, which brought forth their young alive. Sharing

the shallower depths with them were giant amphibians, with limbs adapted for progress on the land. Some types of reptiles made their home permanently on land, browsing on the luxuriant vegetation which earth afforded; but they were themselves the prey of carnivorous species of their own order. The dinosaurs — the "terrible lizards" — were kings of the earth. Among them were the *Atlantosaurus*, 80 feet long and



THE FIRST AVIATORS: THE REPTILE ANCESTORS OF THE BIRDS

30 feet high at the topmost point; the Brontosaurus, 60 feet long, and weighing twenty tons; the Ceratosaurus, smaller in build but larger of brain, and apparently of greater activity than some of its contemporaries. There was the Iguanodon, a beast 30 feet in length, whose habits of rising on its hind legs curiously foreshadowed the colossal mammal of a later epoch — the giant sloth of Patagonia.

These fearsome monsters lorded it over the land, with none even to challenge their supremacy.

The carnivorous dinosaur might conquer and devour the herbivorous dinosaur or any other giant lizard not so well equipped for fighting as himself, and smaller fry would be snapped up. The domination of the reptiles was complete. But nothing came of the mightiest of this strange family. Their development lay along purely physical lines. They grew like moving mountains, with huge, unwieldy strength and blind ferocity, but they moved in a vicious circle.

There is a limit to dimensions. The elephant could attain no greater size than the largest of his species now living, unless he evolved a greater number of legs. Nothing further could be done in the way of bulk, and the dinosaurs missed their destiny. The upright gait which they were able to assume gave them unbounded possibilities. Their forefeet had become virtually hands, and as supply has created

demand, so to speak, in the development of species, this greater advantage should have been turned to account, had there been brain power enough to suggest increased use of the privilege. But the opportunity passed. The dinosaur had its chance, but it was as if some besotted giant were placed today to govern a people;

rude strength and ignorance of fear were insufficient, and nature, as if recognizing that here was another of her great failures, turned to another group. A primitive egg-laying creature

was the first mammal which at last arrived; between it and present-day creation the two egg-laying mammals of Australasia, the duckbill and the spiny ant-eater, are the sole surviving links. The first mammal was a small carnivorous creature the size of an opossum, but there was magic

in the new type. From this group arose in time the ancestors of the whale and all its family; the polar bear and the Siberian tiger, the anthropoid ape of the steaming tropics, the camel of the arid desert, the mammoth and the mouse, and, at last, lord of



THE GIGANTIC SHIP-LIZARD OF AGES PAST



THE SABER-TOOTHED TIGER, WHICH THE EARLY MEN FOUGHT

them all, man himself.

At about the same period came the first birds, beginning as flying reptiles, with flesh-eating teeth, with leathery, featherless skin — a new marvel in the kaleidoscope.

Here again was an animal seeming to have destiny ready for its own molding. It had assumed an upright position; the

membrane of its wings left its forefeet free to act as hands. It had a dual method of progression; it had two implements with which to work. But it brought to its new condition the mind of the reptile; it sacrificed brain to feathers and beak; it merged its arms and wrists and fingers in its wings, and left the race to the mammal, then humbly moving about the earth.

Mammalian forms of life multiplied, the reptile form declined. Could some superhuman, whom we may imagine gazing at the nebula from which our globe evolved, have pictured the scene on earth



THE LORD OF LIFE

at this time, he would have had little doubt as to which order would wrest the ultimate triumph. The time for great specialization was drawing to an end. Fishes in bony armor gave place to more generalized, more agile, less heavily protected types. The reptiles, having failed to develop except in bulk, became exhausted. They could not adapt themselves to changing conditions, and, like many other groups since their day, they fell back in the race, leaving descendants, it is true, but none to remind us of their ancient size and might, save the crocodiles.

From one of these many groups of mammals nature had selected a new type for experiment. She gave it warm blood, she decreed that it should not produce young like those of the reptiles, ready to do battle at birth with the rest of creation, but young which should be nurtured by the mother. Affection came into the world when the first mammalian mother suckled her offspring, and with affection came the characteristics which affection suggests — care, solicitude, pity, self-sacrifice. To be enabled to exercise these, an animal must develop its brain, and it is easy to imagine that, in the midst of animals so different from itself, the first mammals must early have risen superior to their contemporaries. They could not otherwise have survived.

But intelligence was still at a premium. The prize was not to be awarded for many an age. Mammals gradually followed in the track the reptiles had pursued to their own undoing. Size, strength, power of resistance to attack, adequacy of battling weapons — these were the determining factors. From lowly forms came forms more highly organized, and type after type grew to monstrous size. The whales, which were originally land animals, found the contest too severe, and retired to the greater freedom and lessened responsibility of life in the ocean depths.

A sanguinary, hideous era followed while the struggle for supremacy was renewed. Strange giant beasts roamed the earth, more fantastic than any pictured by the mind of man. While land connections still remained between the continents, huge monsters developed and roamed from land to land, but climatic changes brought destruction to whole species. The animals that survive are infinitely fewer than those that have been blotted out of the book of life.

The huge carnivores, the saber-toothed tiger, the great cave bear, and other blood-thirsty beasts, must at one time have seemed to have the race to themselves. But again brute power ran its fruitless course; the race was not to these, and their day passed. The reptiles had failed, the

birds had failed, the great monsters had failed. There must be a new type, unless insects were to carry the prize. It is striking to remember that possibilities in the race for mastery lay with certain of the insects. The ants and bees had in them the power of organization and governance necessary as a step towards dominion. That an insect could now alter its structure and characteristics to become a mammal nobody would dream of asserting, though Agassiz laid it down that the possibilities of existence run so deeply into the extravagant that there is scarcely any conception too extraordinary for nature to achieve. But insects appeared æons ago, before the lancelets and the true fishes, the snakes, the lizards, and the birds; there was time for them to have developed along higher lines.

Nature seems, however, to have been satisfied with them, and we must suppose that to a certain extent they have "marked time." Yet they have in some cases brought social life to a higher pitch of perfection than can anywhere else be found beyond the pale of human society. The ant, in point of instinct, ranks above all the mammals save man himself. It gave the world the first and highest example of civic life.

No animal devoting itself only to bodily development, to the upbuilding of bone and flesh and armor, could hope permanently to hold a lead in the race. Such an animal takes no thought for the morrow. The squirrel and the chipmunk and other animals which lay by store for the winter, are ahead of animals ranking far higher in the estimation of man. Dogs and wolves, which hunt in company, are an advance upon the solitary animal.

But nowhere do we find the ability to rule, to control circumstances, to master environment, so well developed as in the ant. It collects its seed, and in due season reaps its harvest. It impresses other animals for service, makes slaves, and—as was sometimes the case in ancient human society—comes in the end to be ruled by them. It keeps cattle, it rules a well-ordered city with admirable discipline, even to the extent of driving out the idle.

Had the ants combined their balance of experience and specialized instinct with greater bodily development, involving greater responsibilities and greater opportunities, they might in course of time have stood forth decidedly as competitors for the higher honors of the race.

But the pageant of life passed on still without a leader definitely chosen. The

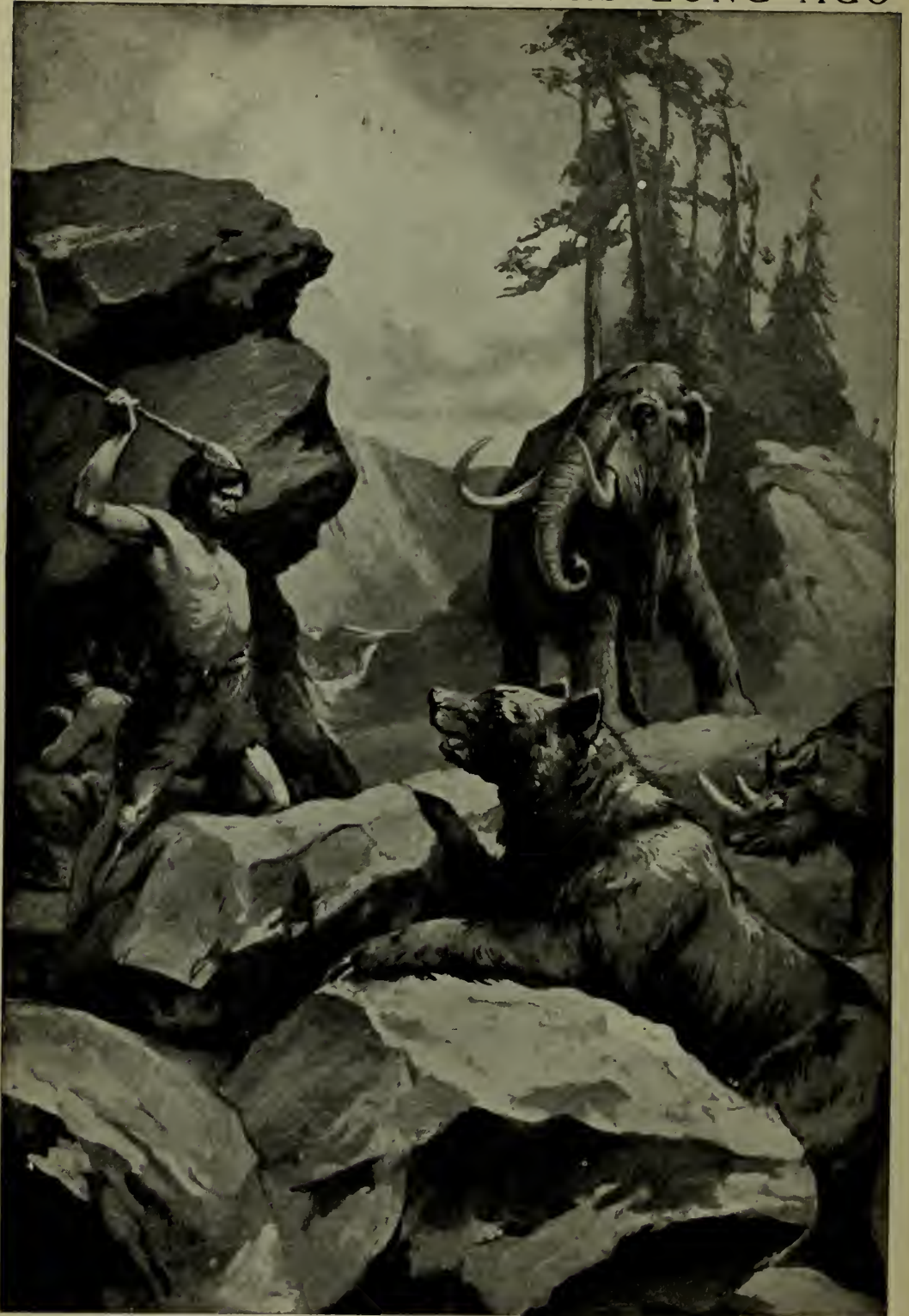


COULD THE ANT HAVE RULED THE WORLD?

Nowhere, except in man, do we find the ability to rule so well developed as in the ants, which enslave other insects—the aphids, shown in the lower picture—into their service. The white ants, or termites, display an even higher intelligence. When the eggs are about to be laid by the queen, they hide her away for a period, as shown in the top picture, where the royal prison-cell is cut in two.

mammalian brain began to develop apace, and physical bulk became of smaller account. The whale survived because its medium was favorable, and its enemies inconsiderable. The elephant, rhinoceros, and the hippopotamus persisted, and they still linger with us. The elephant comes of a form of life which was at one time in the forefront of the contest. Like the

MAN AND HIS NEIGHBORS LONG AGO



The race for the mastery of the world became a thing of stern reality indeed when man came to share the earth with the great monsters. This little man, according to all the laws of chance, should have been gobbled up by a hungry tiger or crushed by a mastodon, and have disappeared forever off the earth.

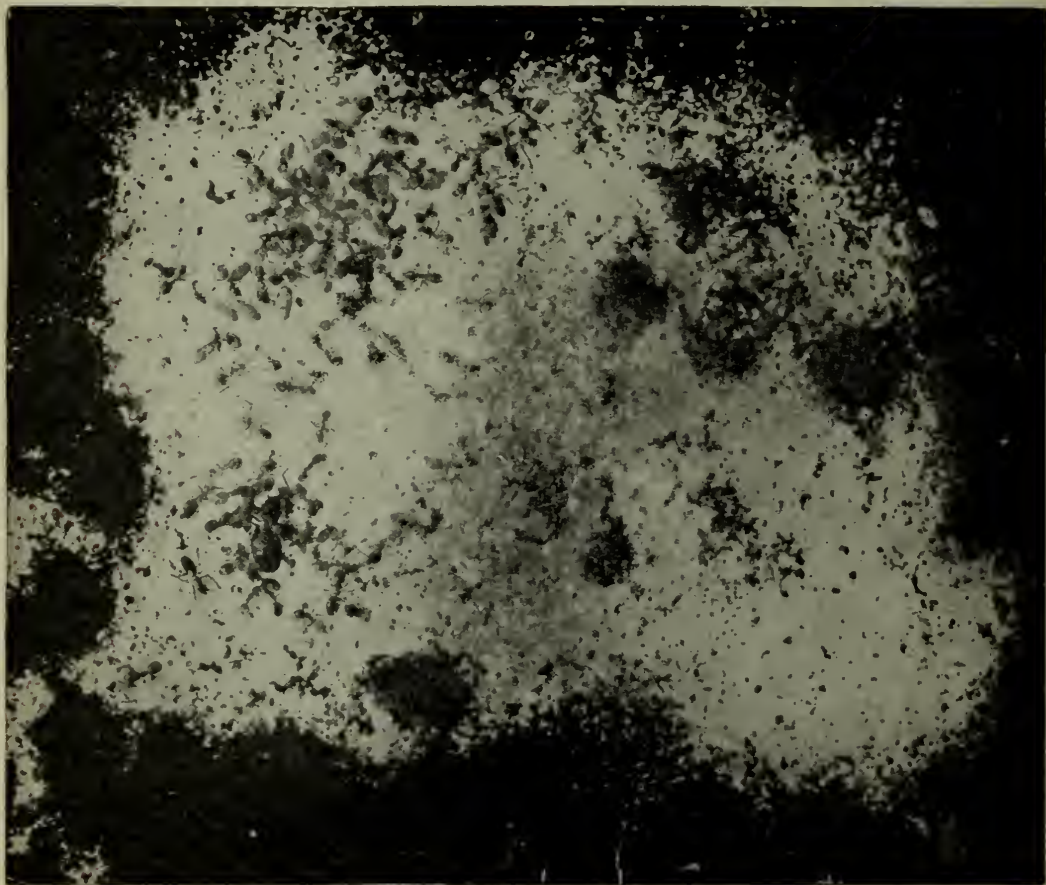
MAN AND HIS NEIGHBORS OF TODAY



But man beat the mastodon. With strength almost unimaginable, with cunning such as man himself can barely foresee, with endurance unsurpassed in any human being, the forerunners of man succumbed to the only animal that can throw a stone. In the animal kingdom man has put all things under his feet.

rest of the giants, he developed from small beginnings, but, unlike the majority of them, he developed brain with brawn and bone. The mental faculties of the elephant have shown a gradual development throughout the ages; and if the elephant could breed in captivity, as our domestic animals do, we should probably have to place him first among intelligent quadrupeds. But every domesticated elephant

with an animal which could carry itself upon its hind legs, leaving the forelimbs free to use weapons and tools. There is no other tool-wielding animal but man. The ants and bees and wasps, the beavers and some of the smaller animals and birds, are wonderful engineers, having mastered problems which man solved through many weary ages. But though the homes not made with hands are wonderful and highly



THE HOME OF THE ANTS, WHICH MIGHT HAVE WON THE RACE FOR MASTERY IF MAN HAD NOT BEEN
Had the ant combined its balance of experience and specialized instinct with greater bodily development, involving greater responsibilities and opportunities, it might in time have stood forth as a competitor for the mastery of the earth. Photos by Rev. S. N. Sedgewick.

begins at the bottom in the task of educating himself in association with man. He must be caught wild, and has no opportunity of handing on his experience to his kind, as do, for instance, the horse and the dog.

And so, inevitably, the mastery of the earth lay waiting for the group from which man was evolved. The task of subjugating the rest of the animal world had to lie

to be admired, there is no hope in them. The reptiles lost their chance when, able to erect themselves, they made no better use of their forelimbs than the kangaroo makes today. The birds muffled their hands in membranes and feathers; the bats chose wings in place of hands; the giant sloth, which pulled down tree-tops with his forelimbs as he squatted upon his mighty haunches, had not brain enough

EYES OF FIRE THAT PIERCE THE NIGHT



Life, which brings forth the beauty of a red rose and the music of the nightingale, brings forth, too, the terror of a roaring lion, prowling through the forest by night, as painted here by Mr. Briton Rivière, R.A.

to go a step further and keep himself alive. Certain rodents are among the types which have retained some power of the hand in their forepaws, and birds of the parrot tribe extract similar service from their claws. The elephant has a wonderful implement of prehension in his trunk, but he would require two trunks to wield a tool.

The Primates had to come, and an aberrant type to bring forth man. "Structure for structure," says Huxley, in a well-known passage, "down to the minutest microscopical details, the eye, the ear, the olfactory organs, the nerves, the spinal cord, the brain of an ape or of a dog correspond with the same organs in the human subject. Cut a nerve, and the evidence of paralysis, or of insensibility, is the same in the two cases; apply pressure to the brain, or administer a narcotic, and the signs of intelligence disappear in the one as in the other. Whatever reason we have for believing that the changes which take place in the normal cerebral substance of man give rise to states of consciousness, the same reason exists for the belief that the modes of motion of the cerebral substance of an ape, or of a dog, produce like effects."

So that man, let us say, was inevitable in the scheme of things. We know nothing of the language of animals, though we realize that they have some mysterious method of communication. Man is the only animal with ordered oral speech. Without him there would be no language, no music save that of the birds. There

would be no building on earth more ambitious than the earthen city of the ants, the dam of the beaver, the hive of the bee, the subterranean colony of the rodent. Man, emerging from his fetid cave, and abandoning his kitchen refuse heap, has steadily ascended in the scale of life. He has defied the laws of nature, for when conditions which should have killed him have come, he has adapted himself or risen superior to them. He has bent natural laws to his purpose. Nature has hounded to death far more types of life than now exist upon the earth. She has heaped scourges upon man himself but man has wrung from her many of her subtlest secrets, and he looks hopefully forward to a future when he shall have conquered them all, and become indeed the master of the earth.

There were sovereigns of this earth before man lived, but they were unconscious both of their sovereignty and of the possibility of self-improvement in point of the only quality that counts—brain. Man alone has developed the masterful brain which wins lordship over the earth and all that is in it. The struggle has been fierce and prolonged, but the victory is inestimable. Meanwhile the animal nearest akin to man in the lower scale jibbers among the trees, affectionate to its kind, compassionate, faithful unto death; dreadfully human in some aspects, dreadfully brutish in more; as inferior to the lowest savage as that savage is inferior to Shakespeare.



A SCIENTIFIC RECONSTRUCTION OF THE GREAT MONSTERS THAT ONCE ROAMED THE EARTH

THE MASTER OF THE EARTH

The Difference that makes the Difference in Man — How his
Improvement in Mind and Hand made him Lord of Creation

THE MOST ASTONISHING THING IN NATURE

“What is man, that Thou art mindful of him? Thou hast made him a little lower than the angels, and hast crowned him with glory and honor. Thou madest him to have dominion over the works of Thy hands; Thou hast put all things under his feet: all sheep and oxen, yea, and the beasts of the field, the fowl of the air, and the fish of the sea, and whatsoever passeth through the paths of the seas.”

WHAT is man? remains the question of questions now, as it has for ages been. The “lord of creation,” on whose dead body the worms feast, the paragon and paradox of animals, asks what he is. But in our own time the question is nearer answering than ever before. The nineteenth century established staggering yet evident truths which not even the ignorant now challenge, and the twentieth may establish truths regarding man’s mind no less notable.

In this initial chapter of the study of man it is open to us to adopt either of the two tendencies which for half a century have divided the students of this subject. They are well defined, and there is no mistaking to which party almost any writer belongs. We may insist upon the numerous radical, profound, unchallengeable, all-significant resemblances between man and the lower animals, and may demonstrate beyond question that he is their relative in the sense that the fundamentals of his constitution are the same as theirs, that his body has the same needs and the same destiny, that his young pass through similar stages, and even that, at certain of these stages, they are actually indistinguishable from the young of many of the higher animals.

Meanwhile, we may slur over or minimize any differences as non-essential, superficial, or trivial. It is true that, by this method, we shall succeed in leaving man wholly unexplained as regards his record and his place in nature, but if our object is to show that he is only the most modern of the higher animals we shall be content.

On the other hand, we may prefer to insist upon the numerous radical, profound, unchallengeable, all-significant differences between man and the lower animals, and may readily convince ourselves, by this means, that he is unique, unprecedented, unrelated, incomparable, an exception to all laws. It is true that this method also has its serious disadvantages, since it leaves wholly unexplained the origin of man, not to mention half his attributes of mind and nearly all his attributes of body.

Science, however, so long as it is true to itself, must ignore or despise no order of facts. Its object is truth, of which all facts are part. If the body of man displays some hundreds of definite anatomical characters which it shares with the higher animals, science must reckon with this fact and its meaning. If the mind of man displays powers so far transcending the utmost displayed by any other form of living nature that we are almost entitled to call him supernatural, if his genius in a hundred directions is as unimaginably novel as his backbone or his muscles are archaic, science must reckon with this fact, too. If there is apparent contradiction, it must be faced, with the full assurance that it is only apparent.

Here, then, we take no side. Disraeli's contribution to the mighty controversy of the last century was to declare that, if asked whether man is "an ape or an angel," he was "on the side of the angels." Science cannot afford either to take sides or to satisfy itself with smart antitheses. Man is neither an ape nor an angel, although he may display attributes of both; and if we are ever to understand him — which means understanding ourselves — we must pay equal attention to the noble reason, the infinite faculties, and the apprehension "how like a god," which his greatest poet perceived in "this quintessence of dust." We are for all the facts. If man is a part of living nature, and was so created we are for that; if he transcends incalculably all other living things, we are for that also.

The mark of man that distinguishes him from the rest of the animal kingdom

Plainly, our first concern is to observe and define those characters by which we may identify the human species. This is no more for the purpose of exalting or depreciating man than if we were seeking to define and distinguish the horse and the zebra, or the oak and the elm. Man forms a species of the animal kingdom, and his specific characters must accordingly be defined. He is evidently a vertebrate — as evidently as the herring, the frog, the lizard, the lark, or the lion. He is no less evidently a mammal — a member of the great mammalian order, whose mothers suckle their young; and there can be no question as to the particular kinds of mammalia to which he is most closely allied. He is far from the whales and the rabbits and the bears and the cats. In anatomical structure he resembles the lemurs, monkeys and apes, especially the apes. Four species of apes come nearest to him — the gibbon, the orang, the gorilla, and the chimpanzee. He and these may be ranked as Primates, or first among mammals. And when his place in the animal kingdom has thus been established, we must observe the characters by which his species may be distinguished even from those which most closely approach it.

The things that belong to man alone, by virtue of which he is man

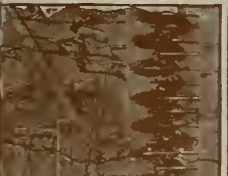
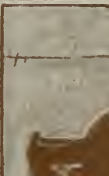
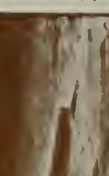
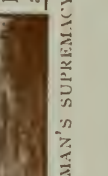
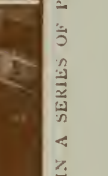
There is, of course, a multitude of differences which are distinctive and might be described at any length. Man's hand and foot are his, and not another's. Man has a well developed chin, and has visible hair on only certain parts of his body. Our immediate concern, however, is with greater things, much less obvious, it may be, but greater, because *they make the difference*. Man is not man because of his chin, nor because of his apparently denuded skin, nor the angle of his jaw. These, and a hundred other peculiarities, are very interesting and notable, no doubt, but our first concern must be with what makes man man. He can think and reason, and speak and write, and imagine. In part the creature of environment, like all other living beings he can also create environment according to the pattern of his fancy, can "shatter it to bits and then remold it nearer to the heart's desire." His chin, his skin, his heels will not explain these deeds, and we want the facts which do.

Let us observe, then, first, that man the erect is also "man the erected," as Robert Louis Stevenson calls him. The lower animals, when possessing them, use all four limbs for the same purposes; they are both four-footed and four-handed — so far as they go. It is true that, in some degree, they foreshadow what is to come. They are not erect, but at times they are semi-erect. The gibbons spend much of their time erect, but that is because they hang vertically by their hands.

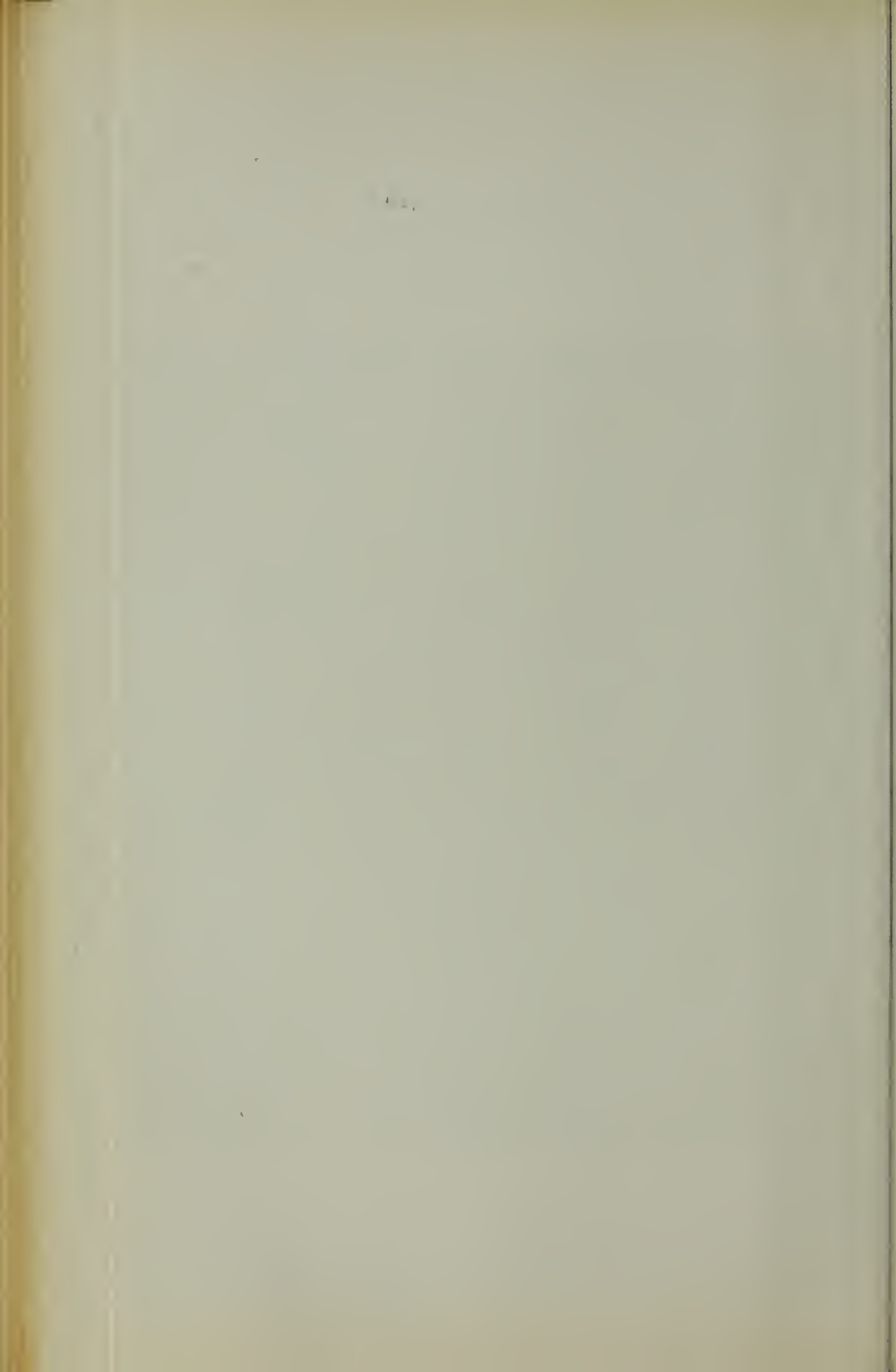
The change in the mechanism of a man by which he is erected

The gorilla may support itself by a stick, and so approach the "upright posture" or "erect attitude," which all anatomists agree in stating as the first distinctive characteristic of man. But the erect attitude can only be temporarily assumed by any ape. The mechanics of its body are against it from the first, just as they are against it in the body of the young baby.

THE RISE OF MAN AND HIS CONQUEST OF NATURAL FORCES

THE STEPS OF POWER Man Discovers the LEVER			THE TRIUMPH OF MAN It may be thousands of years became a miner; he sank shafts in flint-pits and connected them by galleries. Then, in the river-beds, he found pebbles containing copper, and became a smith. The Age of Bronze began.			Ages elapsed before iron was used, but, meanwhile, the primitive wheel had been invented, and by the hand of war tribes had been shaped into nations. Probably the mental power of the higher races was as high then as it is now; what was wanted was a scientific method of studying the properties of things. The Greeks arrived at an incomparable height of artistic genius, and Hero of Alexandria invented a kind of steam turbine, but nothing very important was added to the power of mankind till Watt made his steam-engine.			During the last hundred years the Age of Steam has come and is passing away, and the age of gas and electricity is present. Man has developed the airplane and perfected it for military and civil uses. He travels the seas in monstrous ships like the <i>Leviathan</i>, and he has perfected the radio by means of which he keeps in touch with current and social events.			The Dawn of the Modern World			Man Harnesses the Forces of the Sky			THE AGE OF ELECTRICITY			Suggesting the new powers of mankind indicated by wireless telegraphy, the searchlight, the submarine and the electric dynamo which drives a city.		
--	--	--	---	---	---	---	---	---	--	---	---	--	---	---	---	---	---	--------------------------------------	---	---	---	--	--

THIS CHART REPRESENTS, IN A SERIES OF PICTURES AND NOTES, THE GRADUAL ACHIEVEMENT OF MAN'S SUPREMACY IN THE WORLD



The posture of the body really depends upon the position of the hip-joints. If we examine the body of any ape, we find that a line, dropped to the ground from the "center of gravity" of the body, passes in front of the hip-joints. The upper part of the body, therefore, necessarily tends to fall forward until it is supported by the fore-limbs or arms.

The simple concave-forward curve of a baby's spine temporarily condemns it to a four-footed stage. The bodily center of gravity is situated in front of the hip-joints, and the baby's inability to walk depends partly thereon, and not merely upon lack of practice or upon muscular weakness. But in the course of its development the curvature of the baby's spine undergoes a change. The consequence of this change is to throw the center of gravity of the body behind the hip-joints, so that the erect attitude is not only natural, but inevitable, and the constant tendency of the whole of the body above those joints is to roll, not forwards as in all other mammals, but backwards. There has accordingly been developed, upon the front aspect of each hip-joint, a band of tissue, the largest and strongest of its kind in the body, which prevents the body from rolling backwards, and which, of course, is not to be found in apes or monkeys, who have no need for it.

Man is thus erected. The backbone, which began horizontal in the first fishes, is vertical in him, and this change of axis means almost more than words can say. It is true that, in a sense, the birds are erected also. Their fore-limbs have, indeed, been raised from the ground, but they have not been freed from the purpose of locomotion. On the contrary, they have been more exclusively confined to that purpose, and specialized for it. The bird has gained the power of flight, but it has lost any chance of ever making a flying-machine, or playing the piano, or writing a book. The bird's wing is marvelous in its way, but it is as nothing when compared with the hand of man.

The erect attitude of man is unique, and necessary to his uniqueness, in that it involves the complete liberation of his fore-limbs from the purpose of locomotion. The alteration in the poise of his body is such that he can walk upon his feet alone, and finds that he has his hands free to play with and to work with.

Fortunately they are complete. The vertebrate limb, as we see it represented in the frog, terminates in five digits. In subsequent forms of life some or all of these digits have frequently been lost — as in the whale, the pig, the horse, and even the bird, which has only three and a half fingers in its wings instead of five. In the human line, however, no digits have been lost. Freed from the ground in the erect attitude they are provided with their complement of digits (fingers and thumb), to whose possibilities as servants, and even as tutors, of his brain no limits can be set.

This is the real meaning of the erect attitude as the dominant physical characteristic of man. By the assumption of that attitude he has lost in speed, and is not the climber that the other Primates are. His body is by no means perfectly adapted to it. The valves in the veins of his limbs, for instance, are arranged for the due control of a flow of blood as in a horizontal animal, and are by no means so placed as to suit him best; varicose



THE ANTERIOR GROUP OF THIGH MUSCLES WHICH AID IN KEEPING US UPRIGHT

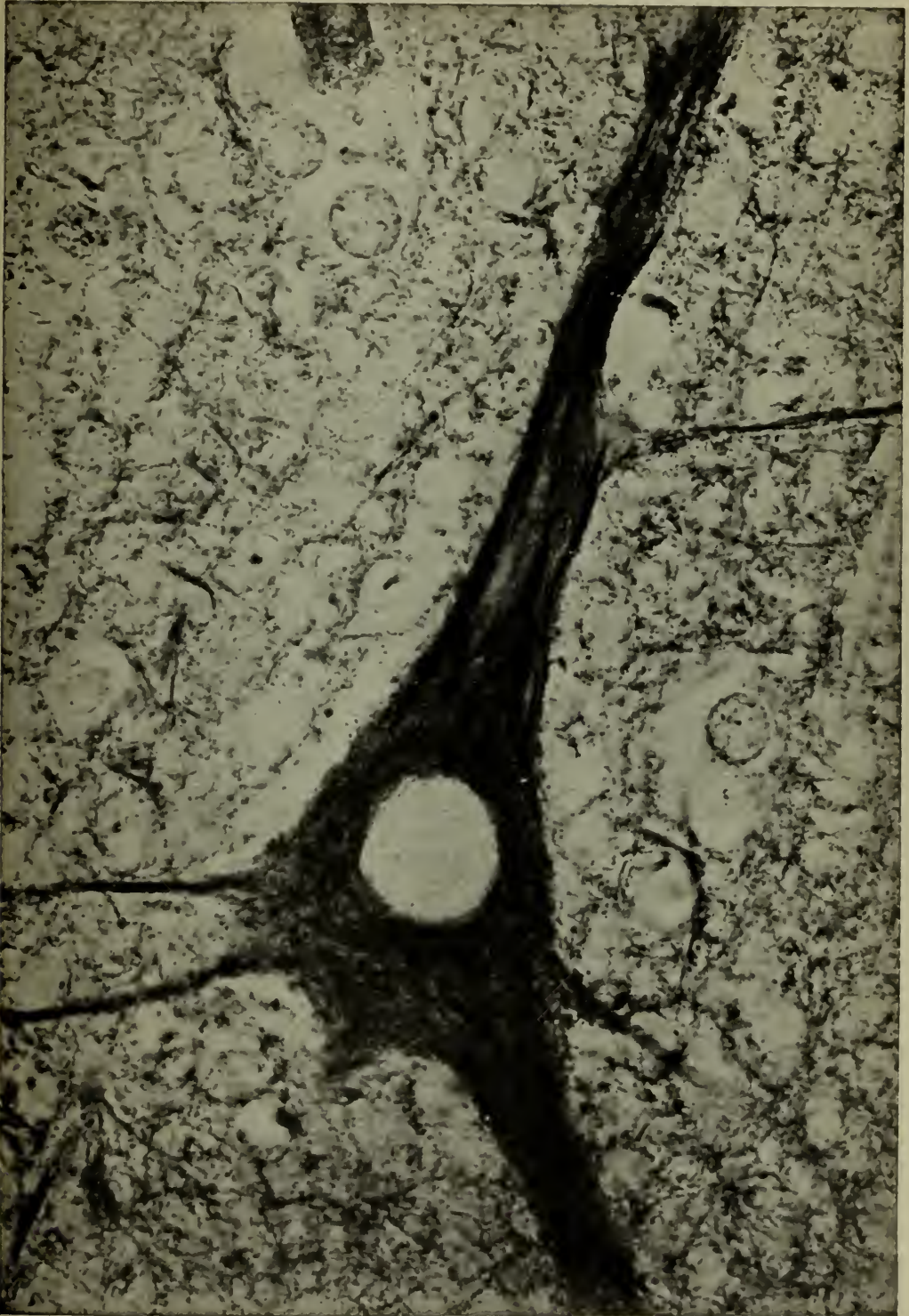
veins are often the price he pays for this innovation. Far more hardly does the erect attitude bear upon women. It is, indeed, the permanent underlying cause of the extraordinary contrast between human childbirth and its parallel in the case of the lower animals. The lower animals normally have but little difficulty in giving birth to their young; whereas in human childbirth it is often necessary, when the obstacles to delivery are so great as to leave no alternative, to remove the child by cutting through the anterior abdominal wall and uterus. Julius Cæsar was brought into the world in this manner and since then such operations are called "Cæsar sections."

THE GREATEST MARVEL OF THE WORLD



REMARKABLE PHOTOGRAPHS OF A SECTION OF THE HUMAN BRAIN, MUCH MAGNIFIED, SHOWING THE
On the left is a section, 5000th of an inch thick, through the gray matter, showing five layers of cells of different structure (numbered on the left). On the right are the fibers connecting the cells. At the top are the molecular cells, and below are three layers of cells of pyramidal shape, with the giant cells—the seat of the voluntary impulses controlling muscular action—in the deepest layer. In the fifth layer the cells are irregular in form. The large photograph on the page facing is a giant cell, magni-

A CENTER OF ACTION IN A MAN'S BRAIN



FIBERS AND THE CELLS THEY CONNECT, OF WHICH THERE ARE PROBABLY THREE THOUSAND MILLIONS tied 1650 times. A center of nerve impulses which control the "doing" of things, it is called a "psycho-motor" cell, because it is not merely motor but voluntary-motor, controlling the action of the muscles of the body. Most of the cells and fibers are, however, concerned in receiving impressions, elaborating them by association, and storing them up in the memory. We know that these cells are the anatomical basis of mind, because they are ill developed in imbeciles and wasted in those who have lost their mind.

The modern anatomist finds himself able, therefore, to translate the story of Genesis into his own language. The curse of Eve, "in sorrow shalt thou bring forth," passed upon her as the price of the knowledge of good and evil, is veritably the price which the Eves of the race pay today for the assumption of the erect attitude, and for the knowledge of good and evil which that attitude has greatly helped man to gain.

The erect attitude raises man's physical stature, of course, and in any case he is a giant compared with the other Primates. The pose of his head, upon his erect spine, further assists him in his survey of the world. His horizon is vastly extended. He gains also in dignity and in all that appearances count for in his control of the lower animals. But when all this is said and allowed for, the fact remains that the attitude in itself is of no moment compared with its all-important consequence — the liberation of his hands.

From this moment onwards, man's hands and his brain act and re-act on each other. Like the apes, man is naturally curious and imitative, as we recognize when we speak of "the pride that apes humility," and his hands serve him at every turn in the satisfaction of his mental tendencies. They are in themselves endowed merely with the senses of pressure, heat, cold, and pain, which are found in the skin at large. But the form of the hands, their power of grasping, the independent mobility of the fingers, together with their naturally rich endowment of nerves, practically supply him with a new sense, as valuable, as educative, well-nigh as distinctive as vision or hearing. He can now study the surfaces, the textures, the consistence, the forms of all manner of objects as never before; and the very instruments of his senses are also, by perfect adaptation, the most admirable

and versatile instruments of his will. We who are now adult forget, and can only remind ourselves by watching babies and young children, how valuable our hands were as means of instruction. The baby handles everything, and commonly carries to its lips what it can grasp. Its lips are even more richly endowed with nerves than are the fingers themselves. Children need constantly to be told not to touch, their natural instinct being to handle and to finger everything, for the sake of knowledge and the power which knowledge bestows. Consider, then, the horse, for instance, who has only two digits in all — one remaining in each fore-limb — to correspond to our hands, and who must use these constantly for locomotion. Since the basis and beginning of all knowledge is sensation — the senses being, as Bunyan called them, "the gates of Mansoul" — what chance has the horse or the bird or any other creature against man, the only or unique owner of two free and perfect hands?

In the nineteenth century, when notions of heredity, such as we must now reject, were unquestioned, this great argument about man's hands and the erect attitude was further extended. It was supposed,

not merely that the hands taught the brain of the individual, but that thereby the native characters of the brain of the race were enhanced; the brain of the child whose father had thus been taught would be naturally the better therefor, and thus, by steady accumulation, we might account for the modern capacities of man's brain, as really, in a sense, the creature of his hands.

This view must now be rejected. The evidence is clear that the brain is the beginner and the beginning. A creature that possessed a less than human brain, but was endowed with human hands, would be far from human, just in proportion to the inferiority of its brain, its hands



THE BABY HANDLES EVERYTHING
The child's habit of grasping whatever comes within its reach is striking proof of the value of the hand as a factor in education.

notwithstanding. We might as well suppose — as many people do, or think they do — that it is the hands that make the mighty surgeon, or pianist, or painter, whereas it is the brain in each and every case. Further, we are clearly satisfied that, notwithstanding popular opinion, the education of the parent's brain is of no consequence to the child's; "acquired characters," or, rather, the *effects of use*, are not inherited. Professor Guyer now maintains that some "acquired characters" are "inherited" and backs up his words with experiments. However, these acquired characters are not the "effects of use." Whatever, therefore, be the

history of the human brain, and however justly we rate the value of man's hand as its servant and instrument of instruction in the individual, we must reject the view that the hand has made the brain in the history of the race. The erect attitude is very important, and man would be somewhat less than man without it, but it cannot claim to have made

man man. More probable, indeed, would be the supposition that the human brain had made the erect attitude possible by its influence upon the structure and balance of the body.

Here, and here only, notwithstanding all else that anatomists may describe, can we discern the differentia, the difference that makes the difference, of man. Man is man not because he has a chin or walks erect, but because he possesses the brain of man. Here we discover new structures, characteristically and exclusively human, in a

degree which is true of no other structure or function of his body. Man's bones and muscles, his teeth and stomach, his liver and lungs, his heart and his jaws, contain and display differences as those of any species do, compared with any other, but they do not display absolute novelties, nor anything approaching them. Indeed, so far as the rest of man's body is concerned, we find that his differences, such as they are, belong to the class of defect rather than excess, minus rather than plus, subtraction rather than addition. This, that, and the other structure he has not at all, or possesses in a diminished form, such as hair and claws, much of the digestive

tract, and many muscular and bony items. If we are to find, anywhere in his body, the key to his status, any physical structure to correspond to his psychological superiority, we must turn in some direction where we can discover not a mere shedding but a positive addition.

It is, of course, in his nervous system that we shall be so rewarded. Not in the spinal cord,

so like that of a host of the lower forms; not in the lower portions of his brain, which control the breathing and the beating of the heart, and the processes of digestion; not even in the brain levels which are concerned with such functions as vision and balance. Not yet do we find anything new, nor, indeed, do we always find that man is here the equal of his inferiors. The process of subtraction, which we notice in his skin, may be observed also in, for instance, that portion of his brain which is devoted to smell — a definitely atrophied sense in man.



THE CHANGE WHICH ENABLES A BABY TO STAND

A baby cannot stand because at birth the bodily center of gravity is in front of the hip-joints, but a change takes place early which throws the center of gravity behind the hip-joints, and the largest band of tissue in the body prevents the body from falling backwards.

Where we come to something absolutely new in man and what it means

Not until we reach the highest thing in man do we reach the new. When we have reached beyond the levels of sense and balance, we come to a mighty fold or mantle of brain tissue which, being comparatively new, is called the "neo-pallium," or new mantle. It is so large in man, so abundant in structures which he alone possesses, that it requires to be folded over all the rest of the brain, which, indeed, it entirely obscures from view. Room for it can only be found, even so, by a process of surface folding, so that it is thrown into a number of "convolutions," with intervening grooves or depressions. Its size, in proportion to the size of man's body, is enormous and unparalleled. Evidently here is something new.

Not, however, until we bring the microscope to bear do we discover what this evident novelty really means. It is covered with a thick layer or bark—as its Latin name, the "cortex," means—of gray matter, much thicker in man than in any other creature, and of far greater extent, since it dips into all the many folds upon the surface of his "new mantle." Examined under the microscope, this gray layer is found to consist of millions of nerve cells, of which the greater number, and the greater number of types, are typical in man. Without them one may be an idiot or an imbecile, having the human form in some degree; but they are necessary for man, since they are the appointed habitation of the human intellect. To the study of this incomparable structure we shall, of course, return. Our present business, in discussing the question "What is Man?" is merely to note that in so far as he can be said to be anything material at all, he is his gray matter.

This is the plus of man, "the little more and how much it is," the difference that makes the difference. It is the stuff that weighs, and yet may sway the sun, in virtue of which he has "put all things under his feet"; and if Carlyle was right in calling genius "the clearer presence of God Most High in a man," then the gray

matter is the very holy of holies, the most tangible and essential incarnation of the Creator in the highest type of His creatures. It is here that life becomes most intense, most original, most creative, most unprecedented, most unpredictable, most infinite.

The paradoxical contrast between man's supremacy and his inferiority

And now it is possible to make an admission which the physical study of man forces upon us. Not only is he *not* "the paragon of animals," if he be thus studied, but he is far from it. All who have thought upon this subject have perceived the paradoxical contrast between man's supremacy in the world and his physical inferiority, for inferiority it certainly is; and all have the more abundantly insisted upon the importance of man's mind, to which his bodily degeneracy lends such point. Said Sophocles: "Many are the mighty things, but none is mightier than man. He conquers *by his devices* the tenant of the fields." Again, consider the famous saying of Pascal: "Man is only a reed, the feeblest in Nature, but it is a reed that thinks." Other authors have been struck by the feebleness of man's body. Shakespeare makes Lear, watching a naked man, say: "Is man no more than this? Consider him well: Thou owest the worm no silk, the beast no hide, the sheep no wool, the cat no perfume . . . Thou art the thing itself: unaccommodated man is no more but such a poor, bare, forked animal as thou art." Similarly, Herbert Spencer tells us how he and Huxley, watching some boys bathing at St. Andrews, "marveled over the fact, seeming especially strange when they are no longer disguised by clothes, that human beings should dominate over all other creatures, and play the wonderful part they do on the earth." Carlyle's famous book on clothes, and the universal practice of savage and civilized man, show how man is really aware of the inadequacy of his "unaccommodated" body to justify his spiritual pretensions.

On anatomical analysis the case against this "poor, bare, forked animal" is clear.



THE HANDS OF A FLYING REPTILE
Showing how the little finger has developed.



THE HANDS OF THE MODERN BAT
Showing the projection of the thumb.

Man is, at birth, the most helpless of all living things, and this helplessness is maintained for an unheard-of period. At his best, so far as defense is concerned, he has neither fur nor feathers nor scales, but is the most naked and thinnest-skinned of animals. He is not only without armor against living enemies or cold, he is also without weapons of attack. His teeth are practically worthless in this respect, not only on account of their small size, but also because his characteristic chin and the shape of his jaws make them singularly unfit for catching or grasping. For claws he has merely nails, capable only of the feeblest scratching; he can discharge no poisons from his mouth, he cannot envelop himself in darkness, nor change his color, in order to hide himself; his speed and endurance is hardly that of a breathless laggard.

Man is at first almost bereft of instinct, has to be burned in order to dread the fire, and cannot find his own way to the breast. His sole instrument of dominance is his mind in all its attributes.

The applicability of mind is limitless. With this one instrument man achieves what, without it, could hardly be achieved — could not, indeed, be achieved — by a creature combining in his own person every kind of material apparatus, offensive and defensive, locomotor or what not, which animal and vegetable life have invented in the past. Man is a poor pedestrian, but his mind

has invented means of locomotion which rival the fish in the sea, the antelope on the land, and even the bird in the air; his teeth are of poor quality, but his mind directs his hands to supply him with arti-

ficial teeth, and enables him to prepare his food. One rhinoceros could dispose of fifty of him, and then of fifty more, but the rhinoceros will fall before his rifle; "by his devices he conquers the tenant of the fields." All the physical methods are self-limited, all involve penalties and hampering restrictions in some other direction, but the method of mind has no limits; it is even more than cumulative, and multiplies its capacities by geometrical pro-



HOW THE HORSE HAS LOST ITS "FINGERS"
Showing the evolution of its hoof.



THE HAND OF MAN COMPARED WITH THAT OF THE MONKEYS AND APES

gression. Is it any wonder then that William Hamilton said: "In the world there is nothing great but Man; in *Man* there is nothing great but *mind* " ?

Man, then, is his brain — more strictly, his neo-pallium. Not only is he it, but by it he lives, by it alone he can survive. That is the least which can be said of it from the standpoint of biology.

Judged, however, not merely as the sole instrument of man's genesis and survival, but as the instrument of his mind, man's brain is evidently the supreme expression of matter, and of the creative forces of life. It is incomparably the most wonderful thing in the world, as it is incomparably the most complex. Before its structure and its functions the sun and the stars and the nebulae hide their diminished heads and pale their ineffectual fires.

In the following chapters we must begin at the beginning — so far as we can discern it — and must follow some rational order. Man's body must come first, from its oldest to its newest — which are its most "nervous" — features. Thereafter we must proceed to study his ego, or self, which manifests itself through his body, beginning there also with the properties he shares with the ape or the ox, as he does his heart or his backbone, and going on to those which are all his own.

Meanwhile we have one more fact to discern. Given that the gray cortex of his brain contains the bodily elements which are new in man, and distinguish him from all other creatures, what is the

psychical character of man which corresponds thereto, if any there be? Can we say that man alone has intelligence, while other creatures have only instinct at the most, and that his gray matter makes the difference?

This 'absolute distinction cannot be made. Man is far more instinctive than we used to realize, and likewise many of the lower animals are far more intelligent than was formerly believed. The difference in man is no doubt enormous, and, of course, depends upon his brain, but it is only a difference of degree. Neither in the sphere of will, nor of reason, nor of memory can we discover any difference between man and his inferiors which is radical, qualitative, explanatory.

The real and crowning mark of man, in virtue of which he is man, is that, while many or all other living beings are more or less conscious, at intervals or always, he is self-conscious; knows that "this is I," feels and knows himself to be himself — an ego, with a history and a destiny, "made with such large discourse, looking before and after," living not only in the here and now, but in the past and the future; not only in the outer world of space and time, but also in an inner world, no less infinite — for it is just as far to the innermost as to the outermost — of feeling and imagination, ideal and resolve; supporting his belief that there is somewhat in him which is "older than the elements, and owes no homage to the sun." It is an "immortal soul."



DAWN — from the painting by Joseph Farquharson, A.R.A., in the Walker Art Gallery, Liverpool.

THE DAY OF A HEALTHY MAN

The Desperate Battle between Health and Disease
That Goes on in Your Body without ever Ceasing

THE TRUTH ABOUT BEING PERFECTLY WELL

HEALTH—which is, indeed, the same word as wholeness and holiness—is what we all desire, whether we know it or not. Happiness is our being's end and aim, but it is certain that, except for very rare souls, happiness and also usefulness are impossible without health.

It is a necessity of our nature, nevertheless, that perfect health is an unattainable ideal. Even the man of mature and certain powers, generally supposed to be healthy, is yet inevitably, in the very act of living and enjoying his health, traveling along the road to more or less imminent senility and death. Our bodies are definitely born to die, and it is almost literally true that we die daily; parts of the body do literally die daily, and at every moment of existence the body contains poisonous products which it urgently requires to get rid of. It seems certain that this removal of waste products is either never quite perfect or else involves a slow deterioration, of which senility is sooner or later the upshot.

Perfect health is, therefore, no more than an ideal, but it is an ideal to be aimed at, and one which the fortunate and wise—but they need to be both—may substantially attain, and maintain even for several decades. Latterly, the standard of activity may require to be slightly lowered, but activity of the highest type, which is intellectual and moral, may maintain its standard, thereby implying a true health of mind, long after real health of body has gone forever.

Our conception of health in this book is not to be merely physical, much less merely muscular, but is to include the whole man, body and mind; and our conception of

the mind is not merely of the powers of reasoning—which are popularly and legally, but absurdly, supposed to be the whole mind—but also the sensations and emotions and desires, the will to do and the will to refrain.

The healthy man is neither he who can run ten miles, nor he who can resist infection, nor he who can maintain intellectual attention for hours without fatigue, nor he who is master of himself in all circumstances. The healthy man is he who has somewhat of all these qualities, and many more. It will begin to be evident already that wholeness means a great deal in this connection; and happy they be who find it!

So complex and various is man, so complex and various are his activities and the possibilities of his environment, that no description of health can really be adequate because none can be all-embracing. Nevertheless, we may briefly describe, by way of a *minimum* indication, a healthy man's day and night; and though the description will consist largely of negatives rather than positives, yet it is very much the satisfaction of these negatives that makes an almost infinite number of positives possible.

Life, as Herbert Spencer taught us, is "the continuous adjustment of internal to external relations." Therefore, when we speak of health, we are assuming some particular or average state of external things; and from this point of view it will be seen that a man may exhibit robust and superb health, in a sense, when he is, say, in the very grip of pneumonia, or when he is lying in bed with a broken leg, or flying in an airplane, numb, dazed, and

half blind, at eighty miles an hour. In each of these cases the man has been thrown by pressure of environment upon his deeper resources, and he may prove that their quality is superbly healthy.

The truth is that normally — that is to say, under such ordinary conditions as commonly satisfy us — we live actually upon the merest margin of our vital resources. Beyond this, we have, each one of us, a further supply which is never ordinarily called upon, and the quality of which we cannot ascertain, nor can anyone ascertain, until we be tested. The depth of these resources also varies for different stresses in different people, and in the same person at different times of life. We have to think of life largely in terms of resistance, and one of us will resist fatigue much better than another, who, on the other hand, will make a better fight against starvation, or enforced lack of sleep, or exposure to cold. We all vary enormously, indeed, in our measure of resistance to different stresses; and it is far beyond the capacity of the cleverest doctor to probe the depth of our vital powers in all possible directions and say what we can or cannot stand.

How we are always, day and night, testing our vital powers in many ways

Yet we ourselves, live we never so wisely, are always testing our own vital powers in most important directions. We go from year to year, but are never called upon to show our mettle against extreme fatigue, or extreme cold, or starvation, or enforced lack of sleep. Yet every day and night of our lives we are exercising our vital forces in resistance against poisoning. This poisoning is partly due to dangerous constituents in what we eat and drink, or dangerous substances made from the food in our bodies. It is partly due to the products of the life of our own tissues, but it is chiefly due to the incessant invasion of our bodies by other living things, which seek to extend their lives at the cost of our own.

The existence of these creatures, which are nearly all of the class called "microbes," has only recently become known; and the fashion in which they cause the greater

part of all ill-health must clearly involve ideas of health which could not possibly enter the mind of the student some half a century or so ago.

The healthy man who goes through danger with almost a charmed life

We meet these chief enemies of our health at every turn. We have only to scratch the skin to know that the microbes of "surgical inflammation" are almost omnipresent. The microbe of tuberculosis is present in about one sample in ten of the milk we drink; and if that milk has never been boiled or "pasteurized," these microbes enter our bodies alive, seeking more and more life at our expense. Practically all milk contains other microbes, possibly dangerous. Uncooked food is generally contaminated, and water, too. We inhale numerous microbes with every breath. Most dust is crammed with them — notably the dust of the streets, and more notably still the dust of living rooms, which the housewife so rightly fears, and, as a rule, so wrongly deals with.

Yet, though possibly dangerous microbes exist in our mouths and throats and elsewhere, and though we are ever swallowing and inhaling new doses of them, we are mostly unhurt; and the healthy man walking through all these dangers bears what is almost a charmed life. Him only the most virulent can touch.

Nay, more. There are many microbes which, if they enter our bodies in large enough doses, or if they happen to be particularly poisonous, will certainly make anyone ill. Almost every child will "catch," or be caught by, measles and whooping-cough; and even the healthiest man, sufficiently bitten by a mosquito conveying the parasite of malaria, or by a rat-flea conveying the microbe of plague, will suffer from these diseases. Yet children who are properly cared for nearly always recover from measles and whooping-cough, and men recover from malaria, and even sometimes from plague. The remedy for these and a host of other microbe poisonings is natural, and may even occur on a definite day, as in the crisis of pneumonia.



Bacilli of bubonic plague.



The rat-flea which carries the plague parasite.



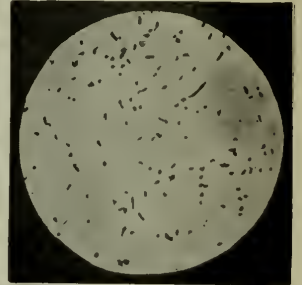
Cholera bacilli.



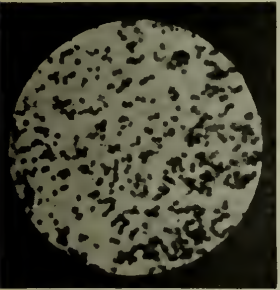
The bacilli of consumption, killing one in eight of all mankind.



Leg of common fly, which carries disease germs.



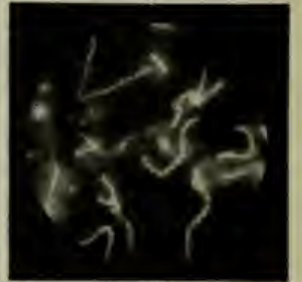
Typhoid bacilli, the author of typhoid fever.



The malaria parasite and the mosquito which carries it.



The yellow fever mosquito and the parasite which it carries.



SIX APPALLING ENEMIES OF THE HUMAN RACE — DESTROYERS OF MILLIONS OF LIVES

Plainly, it depends upon powers of resistance; and if we are to distinguish between the man who inhales tubercle bacilli and kills them, and the man who inhales them to be killed by them; between men who catch a disease and men who, similarly exposed, do not; and between men who, having caught a disease, respectively conquer or are conquered — plainly, we must reach some very deep and real meaning of the word "health," and a meaning which applies to the daily exigencies of life as much as the capacity to digest food. It is just as important for health to digest one's microbes as to digest one's meals; and though the parallel is happy, it is also accurate, for vital resistance, and consequent health, mainly depend upon the production of ferments which digest and destroy invading microbes.

Since these new conceptions were finally established, with all that they involve for the health of present and future generations, we have gone further still, and have tracked down the very elements of our health in some degree. Metchnikoff has shown that the white cells of our blood are among the chief agents of our health, their daily and nightly duty being to search out and arrest and kill forthwith all manner of invading microbes. Metchnikoff therefore calls these white cells the "phagocytes," or "eating cells"; and poor fun, soon ended forever, is their owner's eating unless they do theirs well.

The facts of health in its most important aspect can be actually seen under the microscope, or upon the screen of a cinematograph. The healthy man, having gone abroad and incautiously exposed

himself to the "night air" — in itself delicious and innocent — has been bitten by a female mosquito, which, having helped herself to a drop or two of his blood, has left therein a memento in the form of a few malaria or "bad air" parasites. These seek to multiply in his blood, and there we can see health and disease in visible form, face to face — nay, locked in deadly embrace. A drop of blood from such a man placed on a warmed slide displays Health, his white cells visibly attacking, swallowing, killing, digesting, or utterly disintegrating in their own bodies the black parasites which mean Disease. Half an hour looking at this scene, and Health and Disease are realities henceforth for the rest of the spectator's life.

One thing evidently is certain, notwithstanding an almost universal illusion to the contrary, and it is this — that health or vitality and mere muscularity have no necessary relation to one another at all. It may be admitted that the muscles of a given person are fitter and show better tone — as, for instance, the tell-tale muscles of the face — when that person is in good health than when he is not, but this is a vastly different thing from saying that health is to be attained or maintained by muscular development. It is true that physical exercise may promote health, as by improving the breathing, aiding the digestion, diverting the mind, avoiding *ennui*, facilitating sleep, driving dull care away. These are valuable ends for health, but it is not a question of the number of inches round the upper arm.

"The great vital power of the frail little woman who nurses Hercules"

A final and overwhelming argument against the view that muscularity and vitality are convertible terms is furnished by the contrast between the sexes. Woman, according to that view, is less healthy or has less vitality than man. She is, in the hallowed phrase, "the weaker vessel." Nevertheless, at all ages, under equal conditions, the death-rate among women is lower than among men. We find two or three women centenarians for every man of a hundred.

All through life woman's vitality is superior to man's. She will resist starvation better, or exposure to cold, or exposure to heat; she will survive a far greater loss of blood, far more poisoning, far more fatigue. In the language of the prize ring she will "take more punishment" than he.

How the forces of science are tracking down the very elements of our health

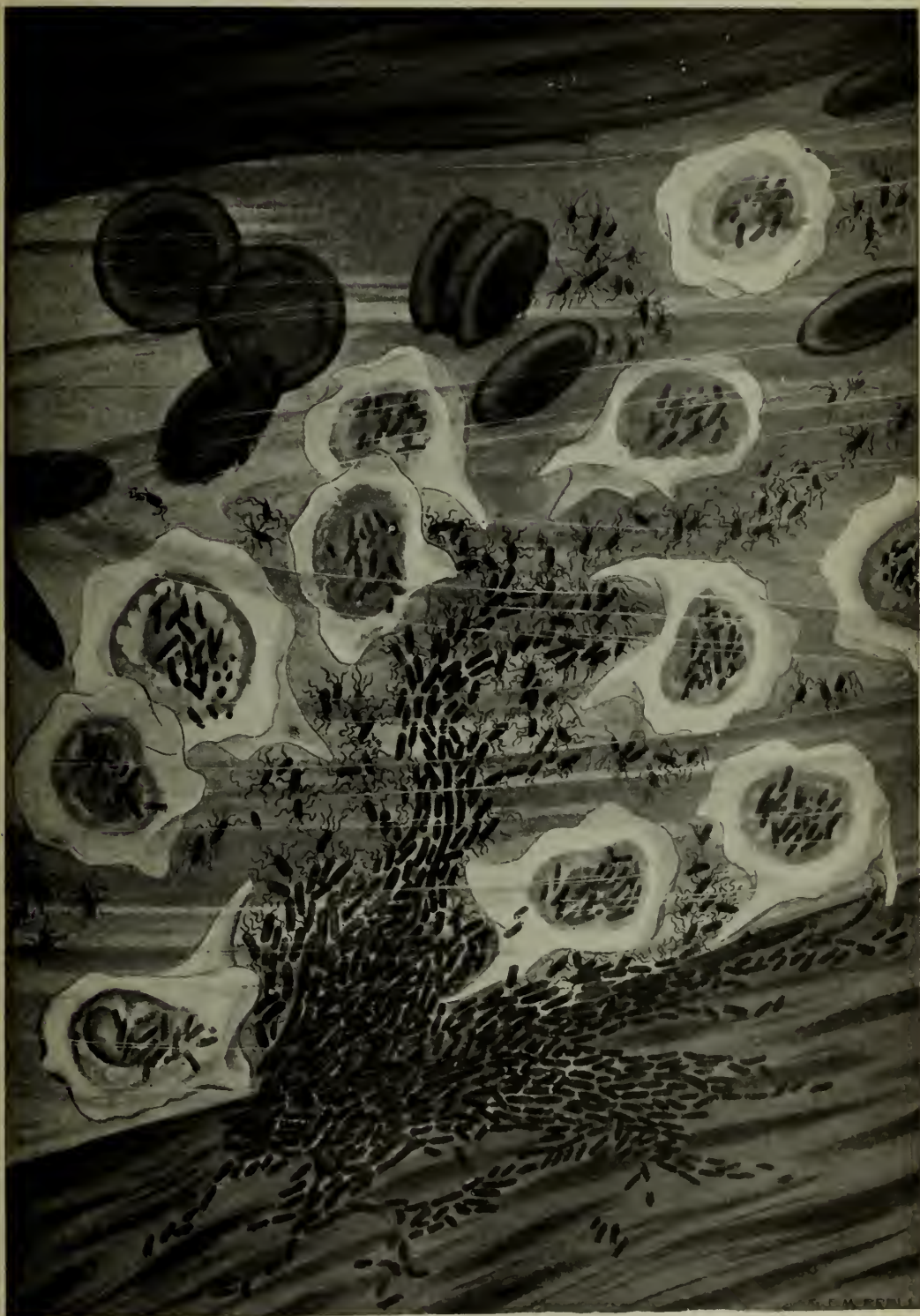
On all counts and at all ages, whether one day or one hundred years, the female organism, which is the less muscular, has a greater fund of health than the male organism. The contention as to muscularity, therefore, breaks down on the first examination; muscularity and health have nothing to do with each other. Your Hercules may be ridiculously susceptible to a cold, a baby at bearing pain, a certain victim to the first microbes of pneumonia that come his way on a cold night; and the frail little woman who nurses him, of whom he could overpower a dozen, will survive him at any vital test which can be named.

All this is not to say that the muscles are not worth exercising; least of all is it to say that the forms of muscular exercise which are involved in play and games, especially in childhood and youth, are not really worth while. All modern psychology teaches us with increasing emphasis that play and games are the normal work of childhood, and that they are definitely constructive of nervous and general health in the future, the impulse to them being as normal and healthful as the impulse towards food. But that does not lead us to the monstrous and incredible theory that physical exercise is the royal road to good health, or that muscular capacity is the index to it.

When the healthy man wakes up in the morning

And now let us consider a night and a day in the life of a reasonably healthy man. From it we can predicate nothing for certain as to how he will face an attack of pneumonia or a staggering grief, but, at any rate, he is better to spend his time as here described than otherwise.

HEALTH AND DISEASE IN DEADLY COMBAT



THE BATTLE IN A DROP OF BLOOD—WHITE CELLS BREAKING UP THE TYPHOID FEVER PARASITE
After looking at a drop of blood through a microscope, Health and Disease are realities for the rest of the spectator's life. Here is what he sees in a patient suffering from typhoid fever—the wonderful white cells attacking, swallowing, killing, digesting, or utterly breaking up the black parasites which mean disease. If the wonderful white cells win, the patient recovers; if, however, the parasites win, he dies.

When the healthy man wakes in the morning he does so spontaneously, for the excellent reason that he has had enough sleep, his brain is completely recreated, all the fatigue-poisons of the previous day have disappeared, and the brain is ready and anxious for spontaneous activity once more. The awakening may be sudden or gradual—that appears to be a detail of the individual—but it is at any rate natural, and of internal origin. Further, if the waking be gradual, it should be entirely pleasant—a feature, indeed, which characterizes the healthy man's proceedings at all times. In some fortunate people this waking period displays unusual forms of mental activity. They get ideas then, write good lines of verse, compose musical phrases, or conceive brilliant dialogue or good plots for stories.

The healthy man who leaves his bed as he would leave a prison

Apart from this, the healthy man, on waking, has no recollections of any state of partial or entire consciousness later than a few minutes after going to bed the night before. In other words, he has had a night of continuous sleep of the priceless kind which involves no dreams deep enough to be remembered on waking. It is certain that we have many dreams which we do not remember; it may even be that there is no such thing as a dreamless sleep, except under the influence of a drug. But our dreams should be so superficial, so to speak, and so vague and incoherent, that no memory of them is retained on waking.

We differ naturally here, as in all other respects, and there are, perhaps, some people who can never obtain sleep of this quality, but they should not be too certain that it is impossible for them. The probability is that broken sleep, or sleep which does not come quickly, or sleep complicated by remembered dreams, owes its poor quality to strain either upon the brain or the stomach, or both, before sleep was sought.

The next fact about the healthy man awake in the morning is that he now wants to be up and doing forthwith. He has had bed enough, and he no more wants

to stay there than to be in prison. It may or may not be that he wants his breakfast. That is not a matter of any significance for health, for it depends upon habit. There are plenty of people to prove that the best way to begin the day is with a hearty breakfast, and there are as many to prove that the "no breakfast plan" has made new men of them. It matters not. One may arrange one's nervous rhythm in any fashion—for breakfast on rising, or for breakfast three or four hours later.

To have a regular and keen appetite is a part of health

But this much may be said: if it is the healthy man's rhythm to have breakfast on rising, then he is ready for it, because to have a regular and keen appetite is part of health. It has to be added, however, that there are conditions attaching to this appetite. In the first place, though variety in food may be welcome, it is not necessary, and the appetite is for food itself; that is to say, it is a genuine hunger, and not merely a wish for scents and tastes in the food. Dry bread, for instance, may taste delicious.

Scarcely less important, both to the man himself and those with whom he lives, is the fact that, though he is ready for breakfast, he is not desperate. He retains his equanimity if it be delayed. "Temper is short in the morning," but his is not. He has slept deeply and well in pure air, and does not display the "breakfast temper" either in waiting for the meal or should there be an untimely interruption during its course; he is "master of himself, though China fall."

How long the healthy man should sleep is not to be measured by the clock

At this point the reader may say that we have forgotten something. How long did the healthy man sleep? To this the reply is that a doctor neither knows nor cares. If we know its character and its fruits, we need not be in the least concerned about the duration of his sleep; it may have lasted five hours—nay, in an old man, it may have lasted four; or it may have lasted nine. People vary individually

A GLORIOUS PICTURE OF PERFECT HEALTH



ONE OF THE FINEST TYPES OF HEALTH — WHOLENESS AND HAPPINESS — IN MODERN PAINTING
"Diana of the Uplands," by the late Charles Furse, A.R.A.

in this respect, and it is extremely probable that we can train ourselves to squeeze more sleep than formerly into a given time. Sleep cannot, indeed, be measured by the clock, for though that will give us length it cannot give us depth, which, of the two, is the more important. The old proverb says that an hour's sleep before midnight is worth two after it, and another says that health and other things follow upon the practice of "early to bed and early to rise." These statements are not true, though they are sufficiently connected with the truth to be useful as a general doctrine. What is true is that the earlier hours of sleep are much deeper and therefore more valuable than the later hours, as careful experiment has proved.

Also, there is much to be said for the doctrine: that if we have a usual hour for bed, it is better not to be much later. Not the absolute hour but the regularity is the thing that matters, though even this is a rule some people seem to be able to defy with impunity.

Now the healthy man has work to do not necessarily for money, not necessarily — if indeed possibly — too irksome, but work nevertheless, and certainly work which involves some measure of effort and entails some vital expenditure. We know this for certain about the healthy man, because we know that no one who has not pleasant and congenial work can be healthy at all.

The importance of a change of interest before you go to bed

It is probable that, if the healthy man's health is to be maintained, his work must be of a kind which, whether in itself or because of some ideal end which it serves, exhilarates him even while it makes demands upon him; and it follows from this that it must be work adapted to his particular capacities and tendencies. Road-making is in itself a useful and worthy thing, but it may not be ideal work for all undergraduates, John Ruskin himself notwithstanding. Another point to be noted is that, no matter whether the work be making a book or a road, it is given up in time for the healthy man to change his

interest before he goes to bed. This will be his heart's desire. It may take the form of bad singing or worse verse; it were well to take the form of a romp with his children — whom the healthy man, in the full sense of the word, can scarcely fail to have, but, whatever it be, it is spontaneous, and therefore in the nature of wholesome play.

The things that the healthy man certainly does not do

Throughout this period, while our friend may have had his anxieties and fears of a reasonable kind, he has had nothing that can be called "carking care," no forebodings or presentiments, no worry in its literal sense of the emotion which strangles the life. About others and their health he may have been concerned, but his own has not entered his thoughts. During the whole of his conscious day his health has been marked not only by positive achievement, but by certain notable negations. He may have occasionally been bored, or even pleasantly tired, but never weary. Of course, he has had no pains of any kind, neither headache nor backache, nor even "hunger pains," if he found it convenient to miss a meal, which the healthy man can do without inconvenience at any time he likes.

Throughout the day, not only has he never given a thought to his own health, but he has been totally unconscious of his own person, and all its parts, save incidentally, when washing and dressing; and even then not quite consciously, for his mind was mostly elsewhere. He has, of course, never once thought about his digestion; and if he were asked about that subject he could afford no further information than that at intervals during the day he enjoyed depositing certain fluids and solids in the largest aperture of his face, but that of their subsequent history he has no record whatever. As for his tongue, he does not remember ever having seen it — he would as soon carry a pocket-thermometer; and indeed he inclines to the healthy view that tongues — unlike children as our ancestors misunderstood them — should be heard and not seen.

**The healthy man who eats and drinks
what and when he likes**

It need hardly be said that the healthy man swallows no medicine, not even a dinner pill. He needs nothing but food and water. His thirst is thirst, and not a crave; his hunger is hunger, and not an itch. He may have taken a small quantity of condiments — other than salt, which is a true food — in his diet, but he did not need them.

His diet was smaller in amount than most of the well-to-do are nowadays content with. This is partly due to the fact that, being healthy, he utilizes all the nutriment he consumes, but still more due to the fact that his desire for food is true hunger — such as many of us have not experienced for years — and also to the fact that he did not stimulate it by any artificial means. Not only is his total diet small, but the quantity of meat in it is conspicuously so, while sauces and soups and gravies have all been somewhat neglected. It is probable, also, that he has retained the sweet tooth he had as a boy. Most men who neither drink nor smoke retain the liking for sweet things, which is characteristic of a healthy appetite. The Germans and the Japanese some years ago increased the quantity of sugar compulsory in their soldiers' diet.

Let us understand clearly that in his eating and drinking our friend is not following a theory or a textbook, or a medical adviser, nor is he in the least aware of exercising any constraint over himself. On the contrary, he eats and drinks what, as, and when he likes. The healthy man neither takes nor requires any so-called "stimulant." Indeed, though in a sense our healthy man is distinguished by nothing more than by his self-control, this self-control involves no real struggle or injury or distress. Having no morbid appetites to deal with, he is without any need for self-control on that score. Being healthy, he is, throughout his entire waking life, blessed with that subtle but priceless form of internal sensation which is called by the psychologists "the sense of organic well-being."

**The man who is full of "pep" and blazes
up on occasion**

He is not overworked nor worried. But from these fortunate conditions of health it follows that the task of keeping his temper perfectly throughout the day is really not a task at all. In no pain or distress of mind or body, having his subconsciousness pleasantly irradiated with the "sense of organic well-being," which is the bliss of the convalescent, how can he lose his temper for any small cause, any trifling annoyances?

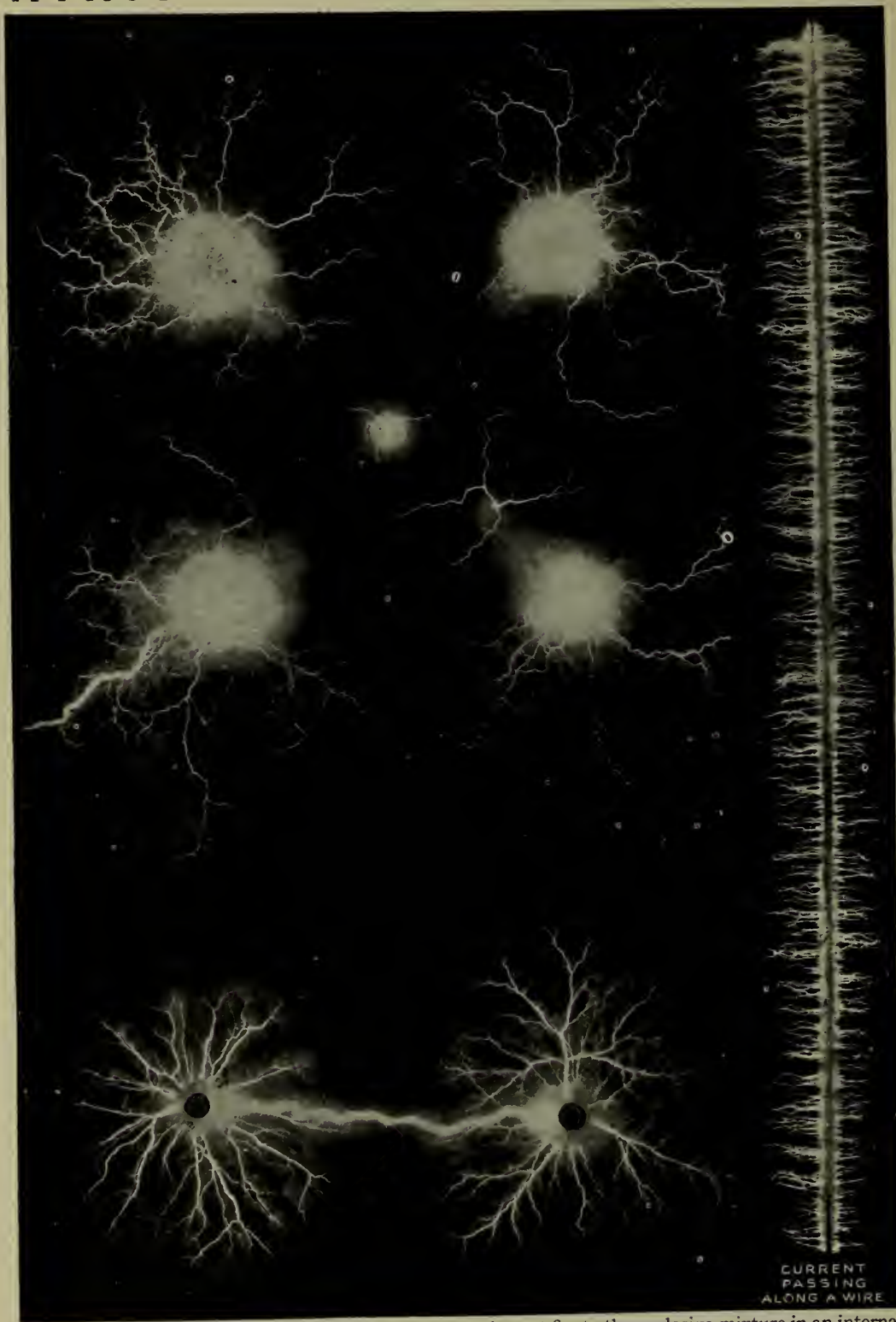
This is by no means to say, however, that our healthy man is somewhat of a vegetable; a useful machine; placid, "safe," but somewhat lacking in color and certainly not "intense." On the contrary, the healthy man is definitely and necessarily active. He is full of "pep," and ready to blaze up on occasion; but when he blazes he burns things that want burning, and does not merely get red in the face and then subside.

His good health provides him with considerable self-confidence and a measure of what may be called "organic optimism" which sets him going, very readily, on all manner of enterprises; nor is he unduly depressed if they go wrong. He does not jump at the slightest sound, nor construct burglars in the night from creaking furniture, but his senses are entire and keen, and give him satisfaction in the using.

**When all the forces of a man say "Let
us be at it again"**

He gets through an astonishing amount of work, and likes it; and he is never more active than when he "takes a day off." He goes to bed regretfully, for there are heaps of things he would love to do; yet when he gets to bed, being perfectly confident that he will soon sleep, he promptly does so, and scarcely stirs until the forces within him say: "Now let us be at it again." He may be poor or rich, humble or exalted in station, but if he answers to this description he is the happiest man alive; nor need you ask *him* whether life is worth living.

A PHOTOGRAPH OF ELECTRIC SPARKS



CURRENT
PASSING
ALONG A WIRE

These are photographs of electric sparks such as are used to set fire to the explosive mixture in an internal combustion engine. They can be made to occur as rapidly as 1200 to 1400 times a minute. These sparks were fixed so that the flashes fell exactly over a photographic plate, and what the eye sees as but a flash is shown to be in reality a thing of remarkable beauty.

MAKING THE WORLD ANEW

The Discoverers and Inventors Who Are Transforming
the Earth and Liberating Mankind for a Happier Life

THE NEW POWERS AND IRON SLAVES OF MEN

MAN is making the world anew. For perhaps a million years and more he has struggled in ignorant misery with natural conditions, but at last he is emerging victorious. In his new knowledge of the laws of nature he has found a key with which he is unlocking the gate to a larger and a happier life.

There are yet many people who do not discern that everything about them is altering; but those who open their eyes and their minds know that the power of modern science is slowly transforming the world. Human life is becoming a divine and lovely thing; poverty is passing away, and disease; and man, by constructing iron slaves to perform the drudgery of labor, is liberating himself for a higher, freer, happier, and more creative existence.

At a leap man has grown, as it were, from an ant into a giant. A few hundred years ago he still used only the simpler forms of the lever in the most ingenious of his tools; animal strength was his chief source of extra-human power; and the most ingenious of his machines did not greatly increase the might of his hand. But now he has quickly gone on extending his knowledge and the marvelous power born of knowledge, until he stands dazzled at the spectacle of the tremendous forces he is gathering into his hands.

Were he now to begin to use these forces with a sound knowledge of their range and quality, he would be able, perhaps in the present generation, to enter into the kingdom of man. He could make the earth his footstool; and thence he might rise, from his study of the heavens, master of the power which fills the spaces of the universe.

But at present our ideas are not commensurate with our powers. We are like a starving man who has suddenly come into an immense fortune without knowing it. That is why we are still apt to see only the darker side of the age of transition in which we live.

Instead of using, for instance, the mighty power of the steam engine with the large vision and the steady forethought it required, we have allowed it to produce on human society the disastrous effect of a blind force. The growth of the great cities of the world, the rapid populating of our own country, the entry of Japan and China into the field of European politics, are among the direct consequences of a trivial event in Glasgow in the middle of the eighteenth century. A model of the pumping engine invented in 1705 by an Englishman, Thomas Newcomen, and already used in a few instances to drive machinery, was taken to an ingenious mathematical instrument maker to repair. When it left the hands of James Watt, in 1769, the engine had been transformed into a mighty power which has produced over all the world a revolution compared with which the French Revolution has no historic importance.

Put on wheels this wonderful thing became the steam locomotive; placed on a boat, it developed into a marine engine; installed in mill and factory, it armed the feeble hand of man with a force to which no limits could be put, and laid a sure foundation for all those future miracles of mechanical power which are to redeem mankind from the harder and duller forms of toil.

Certainly the steam engine has been a great power for good, but much harm also it has done. It has created the industrial slum — the foulest blot that ever existed on this fair green planet of ours. It has brought about a degeneration of some large sections of our working population. For seventy years villages have swiftly grown into immense, somber, and unhealthy cities; and though this growth was almost



HOW THE MICROSCOPE HELPS CONQUER DISEASE

Leptospira icteroides, the yellow fever parasite, first isolated by Dr. Hideyo Noguchi of the Rockefeller Institute for Medical Research. This photomicrograph, taken by him, shows several individuals as seen under the darkfield microscope, magnified 3000 times. The organism is not a bacillus, but belongs to that group of spiral forms which are generally known as spirochetes.

entirely due to the controllable force of the steam engine, no statesman ever tried to make the development orderly, well-planned, and conducive to the general welfare of the race. So, as man failed to exercise his newly won command over nature, the forces he mishandled were turned against him. Nature has still one deadly weapon left against her rebellious son — the weapon of disease — and she has used it ruthlessly.

The defects of civilization which are the main cause of disease

The reader will probably be surprised to learn that there is practically no disease in a state of nature. Disease in both man and animal is the symptom of a defective civilization. Nearly all maladies are produced by microbes, but these parasites live in the blood of wild animals without producing any illness. It is only when man brings his domesticated races of sheep, cattle, pigs, and horses into contact with the microbe that disease originates. It is the same with the plants that man cultivates for his own use. In a wild state, and in their natural soil, the wheat, the potato, and the vine are not hurt by the epidemics which sometimes produce a famine in civilized lands. The fittest in each form of life have been selected by a long, fierce struggle for existence, and brought into a condition of adjustment to their environment.

Quite probably the same thing happened to primitive man. He became subject to disease when, in attempting to build up a civilization he set himself to interfere with the delicate and efficient balance of nature.

The power of the world today to abolish every epidemic disease

In a perfect civilization man, and the animals and plants he uses, would be as free from disease as they are in a state of nature. Means are not wanting to bring about this happy consummation. It has been calculated by Sir E. Ray Lankester that, by the application of known methods of research and prevention and cure, every epidemic disease could be abolished within the next fifty years. Another eminent man of science, Professor Metchnikoff, of the Pasteur Institute, discovered, after many years of study, that what now passes for senility is a microbic disease. He even found the microbe which brings about this premature death, and it is even possible that he has also discovered a method of prevention which will enable man to live, in full possession of his faculties, twice as long as he does now.

THE HOUSE PROBLEM AND RAPID TRANSIT



KIND OF TOWN THAT PEOPLE WILL LIVE IN MORE AND MORE

The diagram in the corner represents the centrifugal force of improved suburban electric transportation service spreading people out from congested centers.



Photo Keystone View Co.

AIRPLANE VIEW OF TYPICAL HOME DEVELOPMENT NEAR SAN FRANCISCO

The business section of the city is easily reached by the new Twin Peaks Tunnel, two miles in length.

THE NEW PROBLEMS IN CITY TRAFFIC



© Ewing Galloway, N. Y.

FIFTH AVENUE IN THE DAYS OF HORSES AND IN THOSE OF MOTORS

The spacious leisureliness of the times so recent yet so completely passed away, compared with the hurrying, feverish congestion which makes such a serious traffic problem in all the great cities of the world, is interestingly shown in these pictures of New York City's finest street thirty years ago and as it is today.

SHANGHAI ADOPTS TRACKLESS TROLLEY



Photos from Ewing Galloway, N. Y.

Busy street in Shanghai before and after the introduction of trackless trolleys replacing the old-fashioned jinrickshaws. At the right a trackless trolley is meeting a touring car. The current-collecting device retains contact with the overhead wires when running as far as ten feet from the wire on either side.



AUGUST 1831 — AUGUST 1921

Comparing the first and the last in railway passenger train equipment: the wood-burning locomotive "DeWitt Clinton" and coaches, the first train to be operated on the New York Central lines, running alongside the "20th Century Limited," the standard bearer of present day New York Central service. This comparison was staged to commemorate the road's ninetieth birthday.

This new power over disease is surely the most important of man's achievements. Without it his triumphs in every other field would but throw a sunset splendor over the history of the human race. Mankind would indeed resemble a young man of genius, such as Keats, who, fatally stricken with consumption, died at the moment when his power promised to equal that of Shakespeare. Now, however, we can look forward with a strong and steady confidence to the future. Not

only have we at hand the means of subduing the strange and invisible armies of death, but we have gone on to harness some of the microbes and make them win us our bread.

A few years ago Sir William Crookes excited serious apprehension by raising the problem of the food resources of the world. One of the capital effects of the modern industrial revolution was to increase in an extraordinary manner the population of some of the more progressive races.



Photo Ewing Galloway, N. Y.

THE NEWEST THING IN RIVER STEAMBOATS

Self-propelled steel barge of 2000 tons' freight capacity operated by the United States government in the South. Started as a war emergency project on the Mississippi and Warrior rivers it has proved a real success and the equipment is being very greatly increased.

CUTTING A FORTY-FOOT SWATH THROUGH A STAND OF WHEAT IN WESTERN CANADA



© Underwood and Underwood, N. Y.

STEAM TRACTOR TRAVELING AT FOUR MILES AN HOUR, PULLING FOUR TEN-FOOT BINDERS THROUGH A FIELD OF DURUM WHEAT

The bogey of an overcrowded world driven to a desperate struggle for food

The large vacant spaces of the earth were quickly peopled, and transformed into great hives of laboring humanity. Abundant food was obtained for these pioneers in the large tracts of virgin soil on which they were slowly advancing. Their advance is now almost at an end; there is no more empty land ahead of them.

Yet in places where they first camped, on the prairie or in the forest, have

mate difficulty, for by enabling man to live and breed in greater numbers science would only hasten the day when a desperate humanity, brutalized by overcrowding and the struggle for food, would return to the most savage form of warfare.

It was a wild prospect—a tragic vision of the mightiest and most wide-spread of civilizations expiring by over-population.

But the ghastly nightmare has now vanished before an apparently slight discovery in the study of a microbe! Plants feed on nitrogen. Up to the present we



© Ewing Galloway, N. Y.

ALL THE COMFORTS OF HOME

Model dairy barn at Rhinebeck, N. Y., built to house Vincent Astor's herd of pedigreed Jerseys. Note the tiled ceiling, walls and floor, porcelain feed and water troughs, model windows and electric lights. Heat from steam radiators enters from holes in the ceiling and passes out through apertures in the walls at the floor, assuring uniform temperature and no draughts.

sprung up huge towns resonant with the roar of machinery and loud with the traffic of long, dark, streaming crowds of workers. Thus there was a universal rise in the price of many of the necessities of life, owing to the general increase in population being out of all proportion to the increase of new wheat fields and new pasture lands.

So on this economic fact there was built a gloomy view of the prospects of the human race. The conquest of disease, it seemed, would only aggravate the ulti-

mate difficulty. When they could not find it, we regarded the soil in which they were planted as infertile, and troubled no more about it. Now, it seems, we can arrange to feed the vegetables we wish to foster. The earth is largely composed of waste nitrogen; there is more of it than the human race will ever require from which to grow food. The question is whether free nitrogen can enter vegetable tissues, and whether certain microbes can continually provide

THE OLD WAY AND THE NEW



© Ewing Galloway, N. Y.

TIN CAN AND 1-H.P.



Photo Pfaudler Co.

GLASS-LINED TANK TRUCK AND 30-H.P.



© Ewing Galloway, N. Y.

LOADING MILK IN CANS FOR KANSAS CITY



Photo Pfaudler Co.

GLASS-LINED TANK CAR

The cars are of steel, lined with glass fused into the metal at an extreme heat. The insulation is so good that the milk retains its temperature within a degree and a half on an 8-hour run in mid-summer. A motor-driven agitator mixes the milk and the cream before they are pumped to the delivery trucks.

the nitric nitrogen on which alone vegetation can feed. Experiments are so promising that it is already certain that a new intensive kind of agriculture will be used



© Major Hamilton Maxwell. From Aëromarine Flying Boat
"PONCE DE LEON" ON THE KEY WEST-HAVANA
CROSSING

A close-up taken from a second flying boat.

in all farming operations of the near future, and that the human race, however it increases, will never fail for want of food.

Yet, though the nightmare of diminishing food has vanished, it has done good service by stimulating thought about another matter of vital interest. People began to ask how it was that the more advanced communities of civilized men did nothing to prevent the multiplication of the unfit, especially of those poor stricken men and

until a thorough investigation had been made of the laws of breeding and heredity. It seemed as though this investigation had only been carried out roughly by breeders of animals and horticulturists; but fortunately some precious discoveries had been made about forty-five years ago by an Austrian abbot, who had been unable to obtain a hearing from men of science in his lifetime, and whose achievements were lost to the world. Some of his papers, however, have now been found again, and on them has been established a new science of heredity and breeding—known as Mendelism, after the Abbot Mendel—to revolutionize agriculture and stock-breeding. This new science promises also to throw much light on the mysterious processes of human life, and perhaps thus give man a strange power over the future qualities of his own race, to its inevitable improvement.

During the time in which these advances



Photos Ewing Galloway

THE LAST OF THE HORSE-CARS

This was the latest cherished relic of New York's primitive transportation systems. More columns of obituary were printed about its passing than about that of any of her most distinguished citizens.

have been made in the control of the forces of life and death and birth and growth, a wide and far-reaching progress has been achieved in many more directions. New discoveries of great importance are taking place almost daily. We live in an age of



GASOLINE-PROPELLED 41-PASSENGER CAR

There is a package compartment just back of the motorman. Fully loaded, the car, which belongs to the Union Transportation Co. of New Jersey, makes 33 miles an hour.

women who hand down to their children the seeds of terrible diseases. The reply was rightly made that man could not control the reproduction of his species

splendid achievement, of glorious inspiration, of magnificent prospect, full of ideas of large scope, capable of exciting the mind to noble enthusiasm.

The new knowledge which is awakening the intellect of sleeping races

We are living in the veritable Renaissance. Compared with it, the revival of learning in the fifteenth and sixteenth centuries was but the faint glimmer of dawn; the stir of new thought in the seventeenth century, the movement of enlightenment in the eighteenth century, were only a distant gleam of the break of day. Now has come full noon; the light of the new knowledge shines over all the earth.

of the strangest and mightiest of the natural powers, — electricity. Its results reach, indirectly at least, into practically every department of our life and we see its effects everywhere. It began in a very modest way and acted as an able assistant to steam. Now we are witnessing a battle for industrial supremacy between steam and electricity and there can be little doubt but that electricity will prevail in the end. At present, however, the invention of the turbine seems to have given to steam a new lease of life.



Photo from Keystone View Co.

SPRAYING INSECT-INFECTED FRUIT TREES BY AIRPLANE NEAR DAYTON, OHIO

A container on the side of the plane was filled with powdered arsenate of lead. Getting to windward of the orchard the aviator released the powder, as shown in the picture, killing all the bugs. From the time he started to spray the trees until he landed he was in the air only 51 seconds. Agriculturists anticipate an extensive use of this system in spraying large orchards.

Under its kindly influence the intellects of the races of the Far East have awakened from sleep; and in Japan great men of science, like Kitasato, are appearing and working in friendly rivalry with the best minds of the European world. In modern science all the higher races are finding common ground where they can meet and understand each other, and work together for the good of mankind.

Perhaps one of the most wonderful achievements that has been attempted during the last century is the harnessing

The marvelous horse-power that lies in the coal mines of the world

It is undoubtedly the most important step in engineering since the days of James Watt.

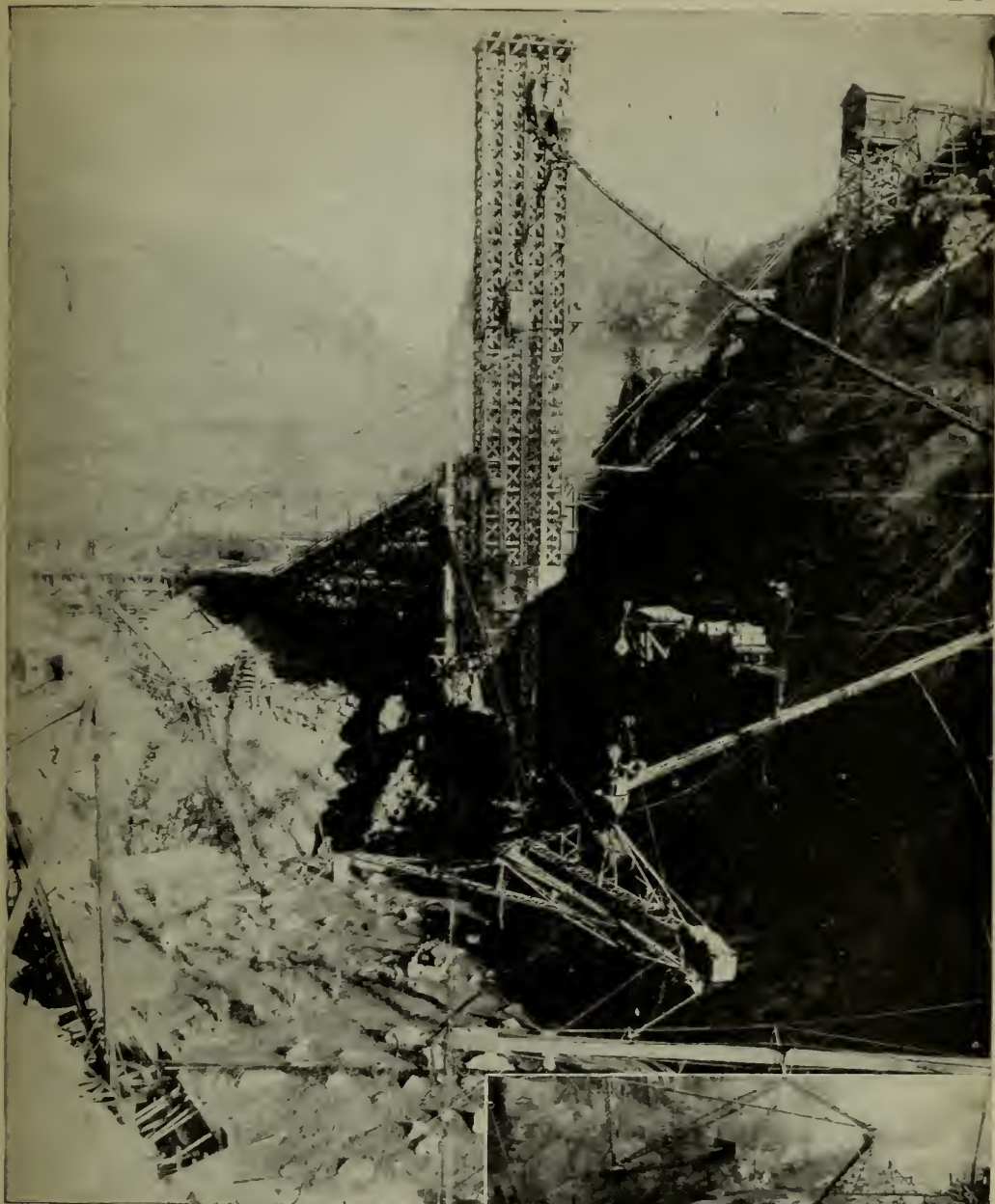
Applied first to the driving of dynamo-electric machinery, it is now being used to revolutionize navigation. By means of the turbine, steamships have been transformed into traveling towns, speeding across the ocean at a record pace, and bringing Europe and America nearer together than Boston and Philadelphia were 150 years ago.

CALIFORNIA'S GREAT WATER AND POWER



The Hetch Hetchy water supply project was designed to make available to the 4,000,000 people in San Francisco and the adjacent metropolitan area, 400,000,000 gallons of water daily, sufficient to satisfy the requirements of the district for a century to come. It is the third largest such project in the United States. The incidental production of 200,000 hydro-electric horse-power will make it also an

PROJECT IN THE HETCH HETCHY VALLEY



ON PAGE TO THE LEFT

(1) Looking up the valley of the Tuolumne in 1915, before construction began.

(2) Looking downstream after excavation had reached solid bedrock, 118 feet below original stream bed, in 1921. The river was turned through a 900-foot diversion tunnel on the left.

ON THIS PAGE

(3) Dam construction brought to original stream level. Concrete is mixed at the bottom of the high wooden tower and raised in elevators to the top of the chutes, which can be moved around so as to distribute the flow.

(4) Close-up of the dam, showing mouth of a chute pouring out concrete. The huge rocks will be embedded in the mass.



important factor in the industrial progress of Central California. The water is to be diverted from the Tuolumne River and some of its tributaries, in the Sierra Nevada Mountains, more than 150 miles from San Francisco, and conveyed to the city by aqueduct and tunnel. The project takes its name from its principal reservoir site, Hetch Hetchy Valley. Our views show it in progressive stages.

It is probable that the next great advance in the power of steam will be effected by some kind of internal combustion engine. At present steam is made by what is practically the primitive method of putting a kettle on a fire. This means an extraordinary waste of energy. If, however, a way were found of putting the fire inside

fifteen billion horse-power for 12,000 years. This estimate will surely be greatly increased when all the coalfields of the earth are discovered.

Yet the age of coal and steam and the smoky industrial cities which they have produced is even now about to pass away. For the era of electricity is at hand. It



© Ewing Galloway, N. Y.

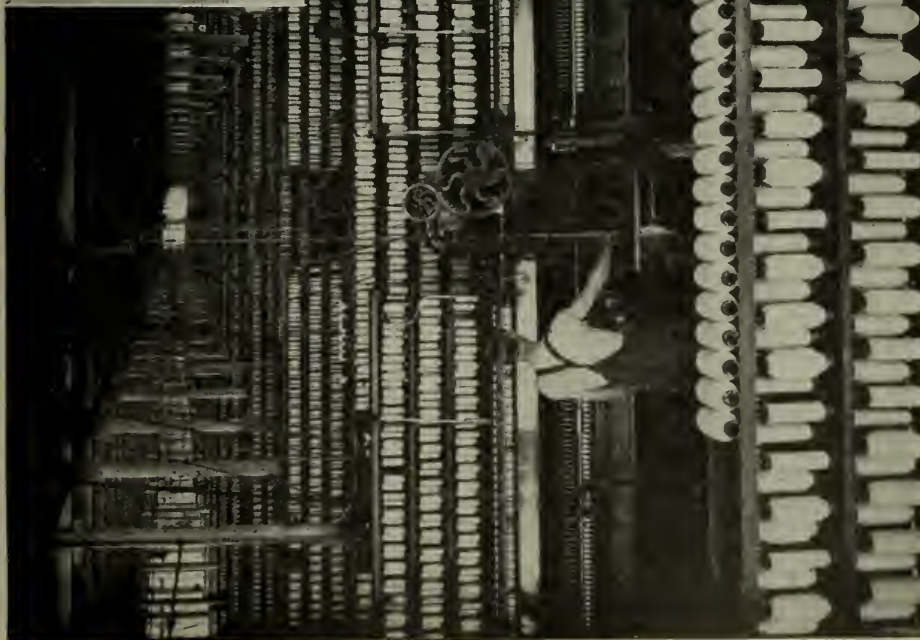
ANCIENT CHINESE ABACUS OR CALCULATING BOARD

MODERN BURROUGHS ADDING MACHINE

the kettle, all the heat would be used in transforming water into steam. Then, if the steam power were directly applied in turning the vanes of a shaft, as is done with a turbine, steam power might forever remain one of the grand forces of mankind. The steam engine is fed by the coal-bed, and there is still available in the mines of the world enough coal to create

is now possible economically to convert coal at the pit-mouth into electrical energy, by using turbine or gas engines, and then by means of wires to distribute the electrical energy to the place where it is needed. We are still waiting for a cheap light, easy means of storing electricity in considerable quantity. Some of the most ingenious minds in every progressive race

REVOLUTIONIZING THE METHODS OF THE TIMES OF THE REVOLUTION



© Underwood & Underwood, N. Y.

MULE SPINNING ROOM IN A BIG COTTON MILL
AT ADAMS, MASS.

Photo Ewing Galloway

MRS. REED'S SPINNING WHEEL
OF REVOLUTIONARY DAYS



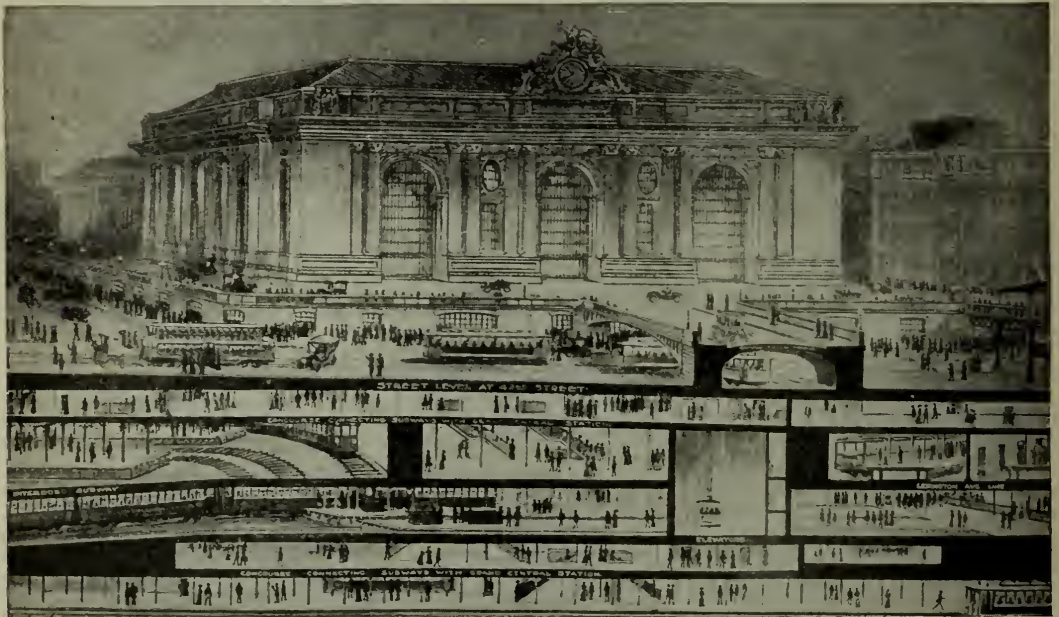
Photo Textile World

FRAME SPINNING ROOM OF THE BRIGHTON
COTTON MILLS, PASSAIC, N. J.

are busily searching for the storage battery which will make electricity the most useful and powerful and varied of all the forces in the service of man, so that it is likely that this very important discovery will be achieved during the present generation.

But it is not merely through a few important or spectacular inventions that man is adding to his powers. Countless small new devices and new discoveries are increasing the convenience and pleasure of civilized life. Many of these new devices are so simple that no one stays to explain them,

the moon might supply energy if they could be transformed into electric power and distributed in a regular flow from a reservoir; the same remark applies to the varying heat of the sun, though in our variable climate perhaps little power is likely to be derived from the direct utilization of solar heat. What is wanted is a new and efficient means of obtaining constant and adjustable sources of energy; and the forces of wind, tide, and sun-rays must go on running to waste until the great storage battery is discovered.



Courtesy State of New York Transit Commission

UNDERGROUND RELIEF OF SURFACE STREET RAILWAY CONGESTION
Complicated network of subways at the Grand Central Terminal, Forty-Second Street, New York.

and they often remain mysteries even to many who constantly use them.

As soon as we can store electricity in any large amount we shall be able to return to one of the most primitive sources of energy, the windmill. Contrary to popular opinion, the power obtainable from the wind is very considerable, and, simple though the windmill is in construction, it is an admirable machine for the purpose. The only disadvantage of wind power is its intermittent nature, and the cost of storage.

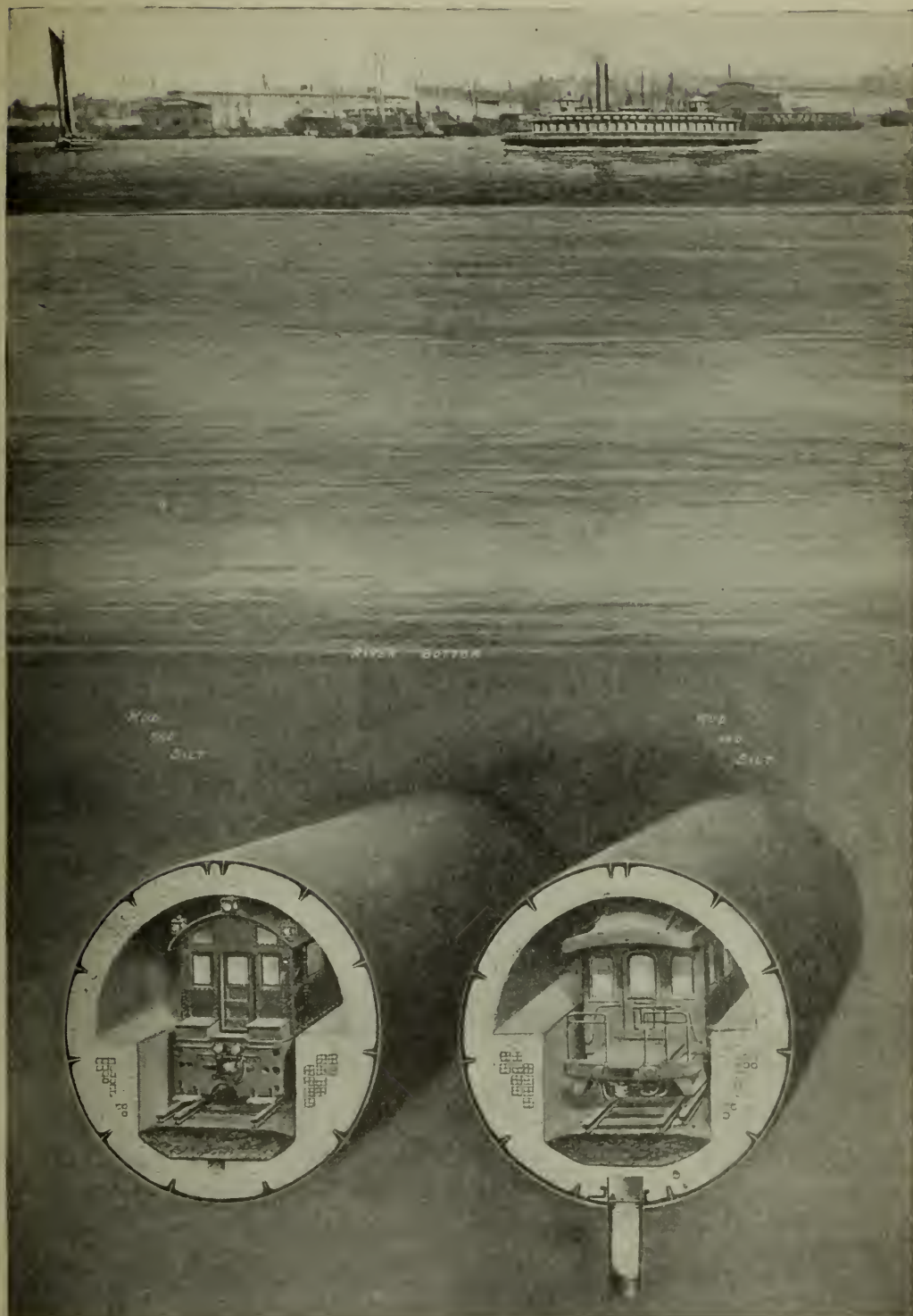
Similar disadvantages seem to attach to all the actual instruments invented for harnessing the powers of the moon and the sun. The tides caused by the swing of

In the meantime, electricity is already in course of changing for the better the conditions of our urban life. In places where there is a large supply of natural power, a new kind of town is appearing.

The pleasant kind of town that people will live in more and more

No forest of factory chimneys darkens the sky and defiles the air of these new towns with evil fumes; no coal fires in innumerable ugly little houses fill the rooms with dust, and thicken the winter fog and soil the summer heaven. Everything in these new towns is delightfully sweet and clean and healthy.

MAKING NEW YORK A WAY STATION



Courtesy of Scientific American

Section showing the Pennsylvania railroad tunnel under the Hudson River at New York. Total length under the water, 6118 feet. Outside diameter of shell, 23 feet. By using this tunnel into the Pennsylvania Railway terminal on the island of Manhattan, and the East River tunnel and Hell Gate Bridge out of it, through trains from the South for New England points make New York only a way station.

Flowers grow in all their beauty around the cottages of workmen, and among the flowers are happy children with rosy cheeks and clear, bright eyes. A single current of electricity does all the harsher toil. Born in a strong stream of water falling from some mountain and swirling a few miles away from the town, the electric force runs along a cable to some distributing house, and thence through a network of wires into every building. At night it fills the streets and the dwelling places of

the electric cities of the future one man with his finger on a lever will be able to control the stream of subtle power for every kind of work required by the community.

Already the cheapness and the infinite utility of electricity are effecting an important change in the industrial power of various countries. Mountainous lands which have been unable to compete with the great coal-producing regions are developing manufacturing centers with immense resources.

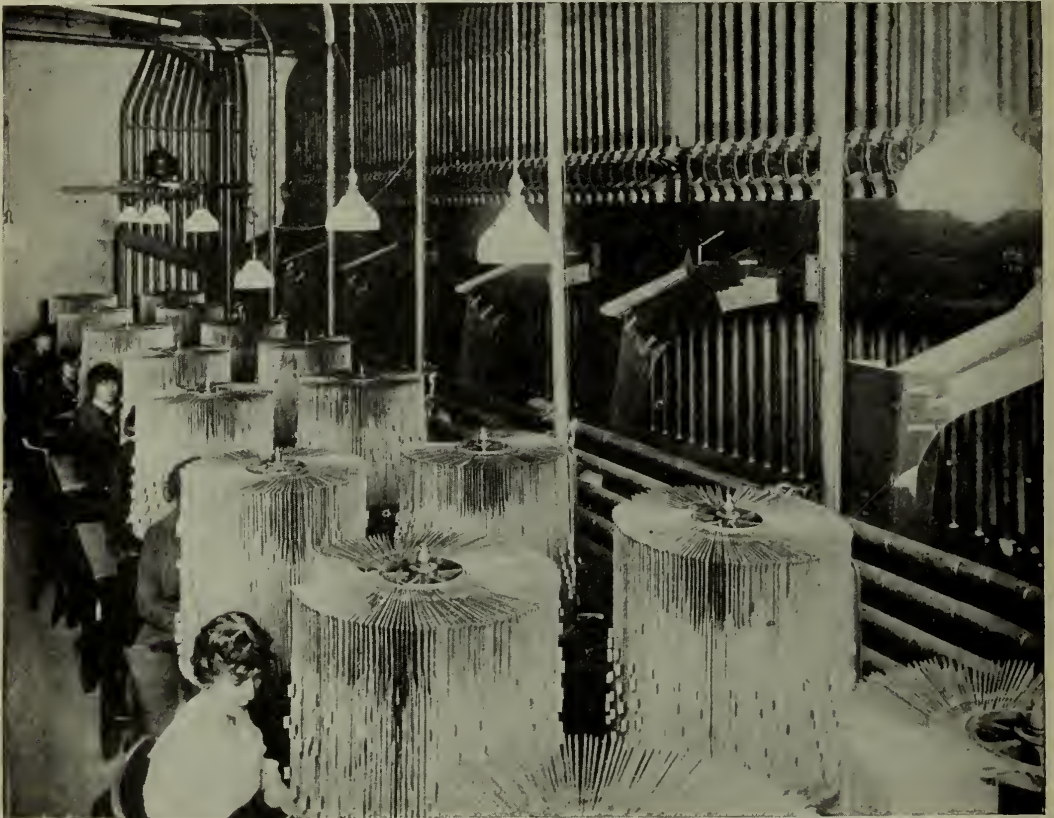


Photo from Ewing Galloway, N. Y.

CHECKING UP CUSTOMERS' CREDIT AT HIGH SPEED

This card index system, in a big Chicago department store, consists of loose card plates on revolving stands. The operator can find a name in one-tenth the time required by the old-fashioned index arranged in sliding drawers. When a customer asks to have a bill charged the sales clerk writes the name on a paper and puts it in the pneumatic tube leading to this room. A girl turns to the name in less than a minute, determines at a glance whether the waiting customer has an account and, if so, whether it is O.K., writes yes or no on the paper and returns it instantly to the proper counter, to which one of the wall tubes runs. The system avoids credit risks on both sides.

the people with light; it can do all their cooking; it links them closely together by telephone and telegraph, and enables them to speak with people hundreds of miles distant. It drives every piece of machinery, and makes even the factory a bright and healthy place of toil. And how docile this terrific force has become! In

The huge possibility of water power and a vision of the electric age

Norway has in her great waterfalls and mountain torrents the power of eight million horses. Recently a single power station at Rjukan increased its capacity from 30,000 to 250,000 horse-power by spending some \$350,000 on a reservoir.

GREAT CHANGES IN PRINTING PRESSES 200 YEARS HAVE SEEN

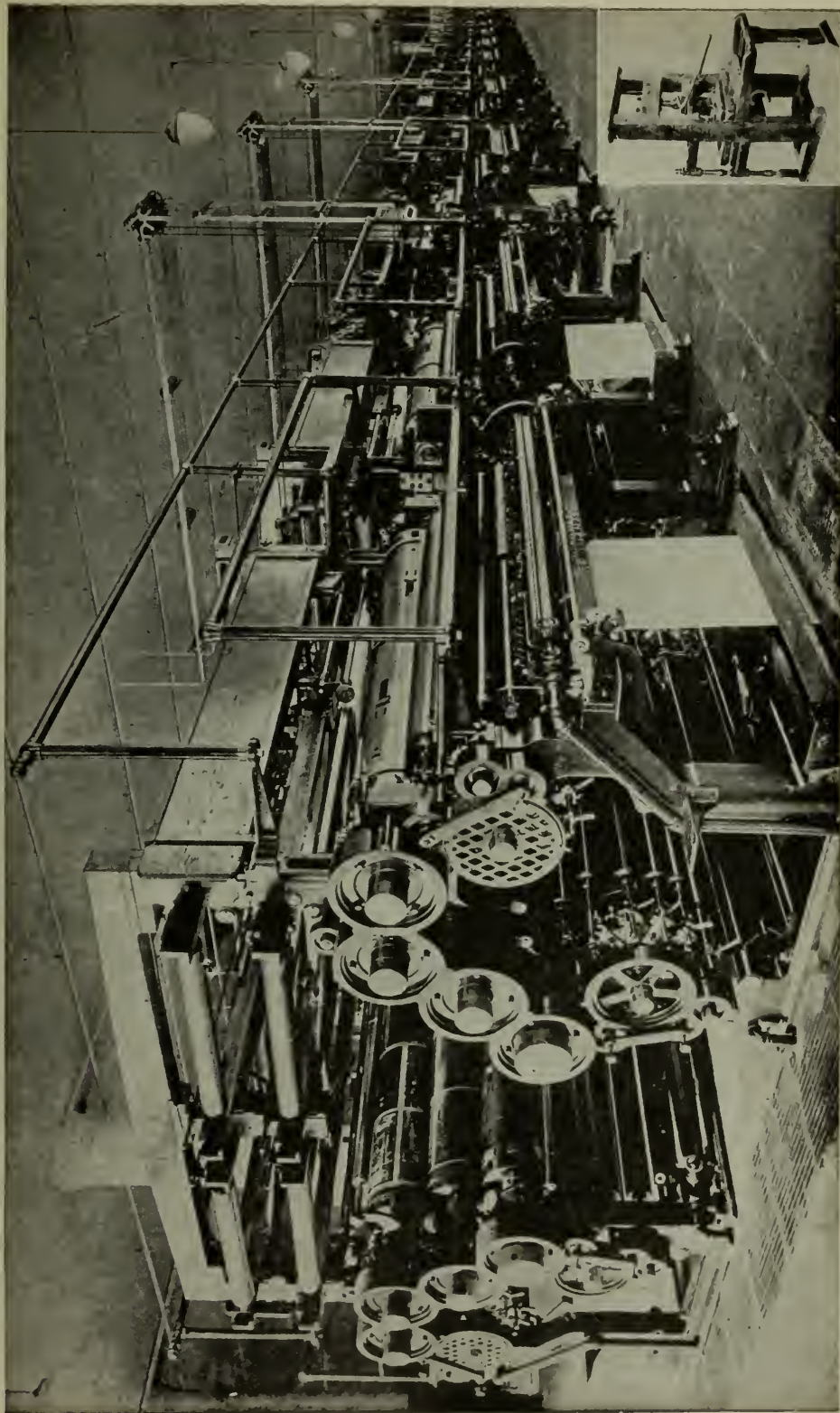
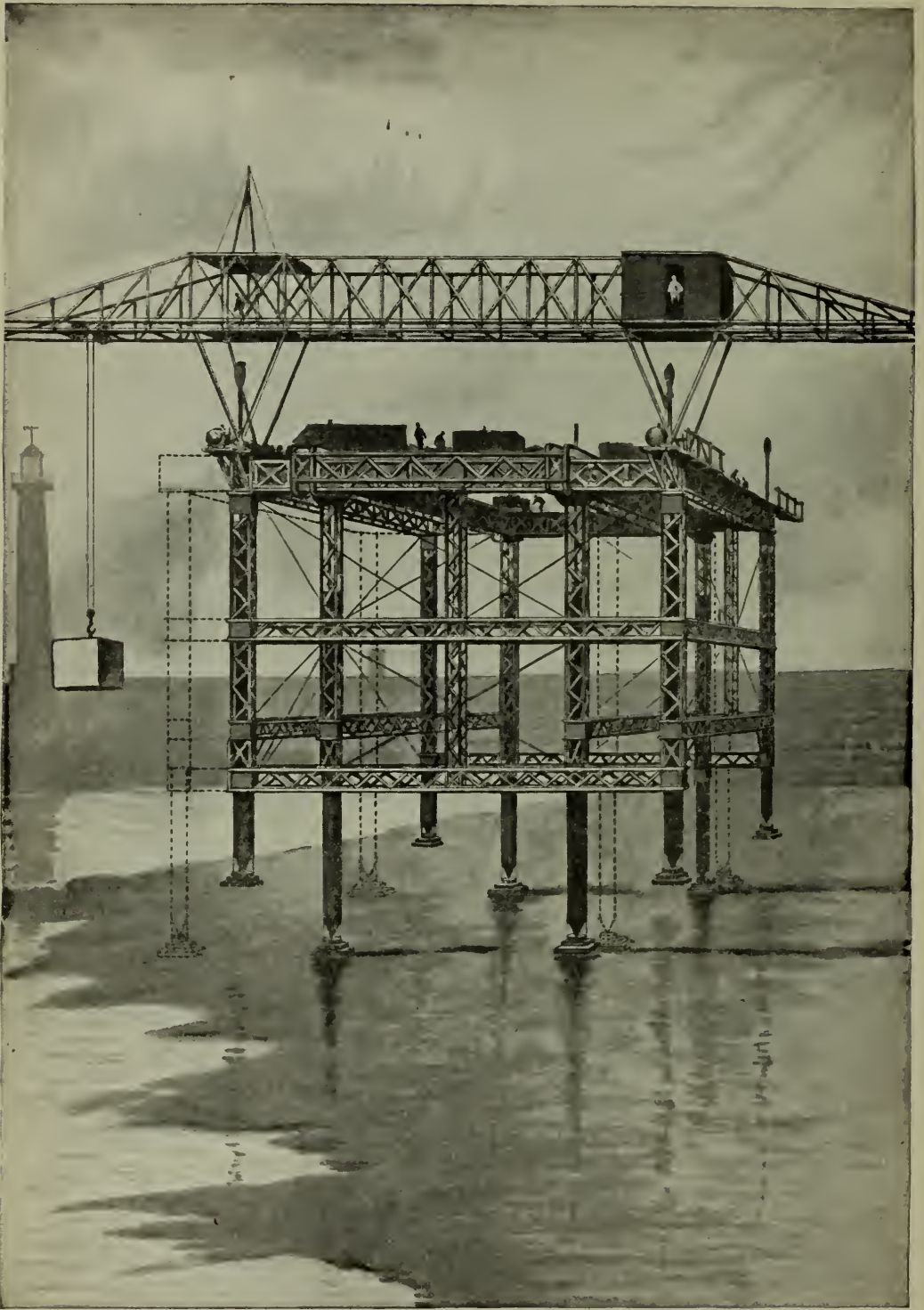


Photo from Ewing Galloway, N. Y.

A battery 200 feet long, the largest ever installed, of Scott Multiple-Unit presses in the plant of the *Detroit News* with a capacity of 432,000 16-page papers printed, folded, cut and counted per hour. The paper is fed to the presses from the basement.

© Ewing Galloway, N. Y.
Benjamin Franklin's
printing press, 1725

A MACHINE THAT WALKS TO ITS WORK



A HUGE STEEL STRUCTURE WHICH WEIGHS 200 TONS, AND MOVES STEP BY STEP AT 40 FEET AN HOUR. This platform, carrying a massive electric crane, has two frameworks, one inside the other, each with four legs. It stands on its outer legs, as shown in the picture. When it is to be moved, the inner stage slides forward or sideways by electricity, and the legs are lowered to the position of the dotted lines. The outer stage then slides forward, the legs rising and falling, and carrying the stage one step onward.

The result of such development is that electricity is becoming much cheaper in Norway than steam power, and the Norwegians are swiftly building up a great industrial future. They use electric furnaces for smelting iron, and by means of electricity they manufacture large quantities of lime, soda, and ammonia—from the air!

This is, indeed, one of the strangest of recent discoveries. Having at last obtained control of nature's mightiest force, man is now exploiting the air as well as the earth, and obtaining from it the substances he requires in his daily life.

But a still stranger thing comes into our vision of the electric age, for electricity is being used in a wider known but scarcely less wonderful way to transmit pictures over an ordinary telegraph wire. A wave of light moves over a specially prepared drawing, and in so doing sets up a series of electric impulses, which reproduce the picture on a drum fixed on a receiving apparatus. In this way photographs can be sent from New York to San Francisco in a few minutes. This device is of great

assistance in newspaper work, where time is so important; also to the police department, in tracing escaped criminals.

The great steel man that strides about the English coast, blasting away rocks

There would seem to be no limit to the use of electricity or to the sort of habitation in which this force may come to dwell.

A London firm of engineers has constructed something like the Martian Man of Mr. Wells's imagination. The Walking Man of Whitby, shown in the picture on the page facing, is an enormous machine, which strides about the coast building harbors and blasting away rock to deepen channels for ships. It has eight legs, and when it is walking on loose ground it wears huge sand-shoes. The legs are worked by electricity, and so is the huge crane with which it does its work. The



Photo from Underwood & Underwood, N. Y.

HOW THEY STACK LUMBER AT PUGET SOUND

This is the way the mill owners have effected a great saving in yard space. The stacks vary in height from 60 to 75 feet and are built with the aid of the mechanical stacker shown. The towering piles of lumber rest upon sills 20 feet below the roadway on which the stacker travels; thus about 35 feet of the stack can be built without mechanical aids.

steel monster weighs about 200 tons, and its legs are 37 feet long. It is so strong that it does not need to move out of the way of the blast of the dynamite cartridges which it uses on the rock beneath. The heaviest sea can break

against it without disturbing it in its labor; it walks out and toils in rough water in Dover harbor when no ship could remain steady for a crane to be worked from it.

The conquering of space and time by electricity is one of the common facts of

life, but a new invention, the railophone, bids fair to do astonishing things. The invention of an electrical engineer enables a passenger in the fastest train to talk with anyone on the telephone system. It may soon be possible to hold a conversation with a man in Chicago while we are traveling through Florida on an express at sixty miles an hour. This, however, is not the most important thing about the railophone. It has a bearing on the development of the railway. Now

that the monorail has become, by the use of the gyroscope, a practicable means of traffic, it is highly probable that we shall be able to speed from place to place at a hundred miles an hour, and one happy result of this will be the diffusion of our now overgrown cities.

A slow railway is a centripetal force; it draws the best life of the countryside into a vast urban maelstrom. The social

history of nearly all civilized peoples for the last sixty years is merely the history of an enormous swirl of population into a magic radius of three or four miles, to suffer there physical and moral disaster less apparently acute, but eventually more appalling to the imagination than any

pestilence that ever swept the world. A very rapid railway, on the other hand, is a centrifugal force. As transportation becomes more rapid and less expensive we see wise people leaving the cities and settling where fresh air and health-giving surroundings abound. And in the cities where factories and power plants have to be, electric power, smoke-obliterating devices, and stricter laws in regard to cleanliness do much toward improving the conditions of such places so that the closely-packed



Photo Underwood & Underwood, N. Y.

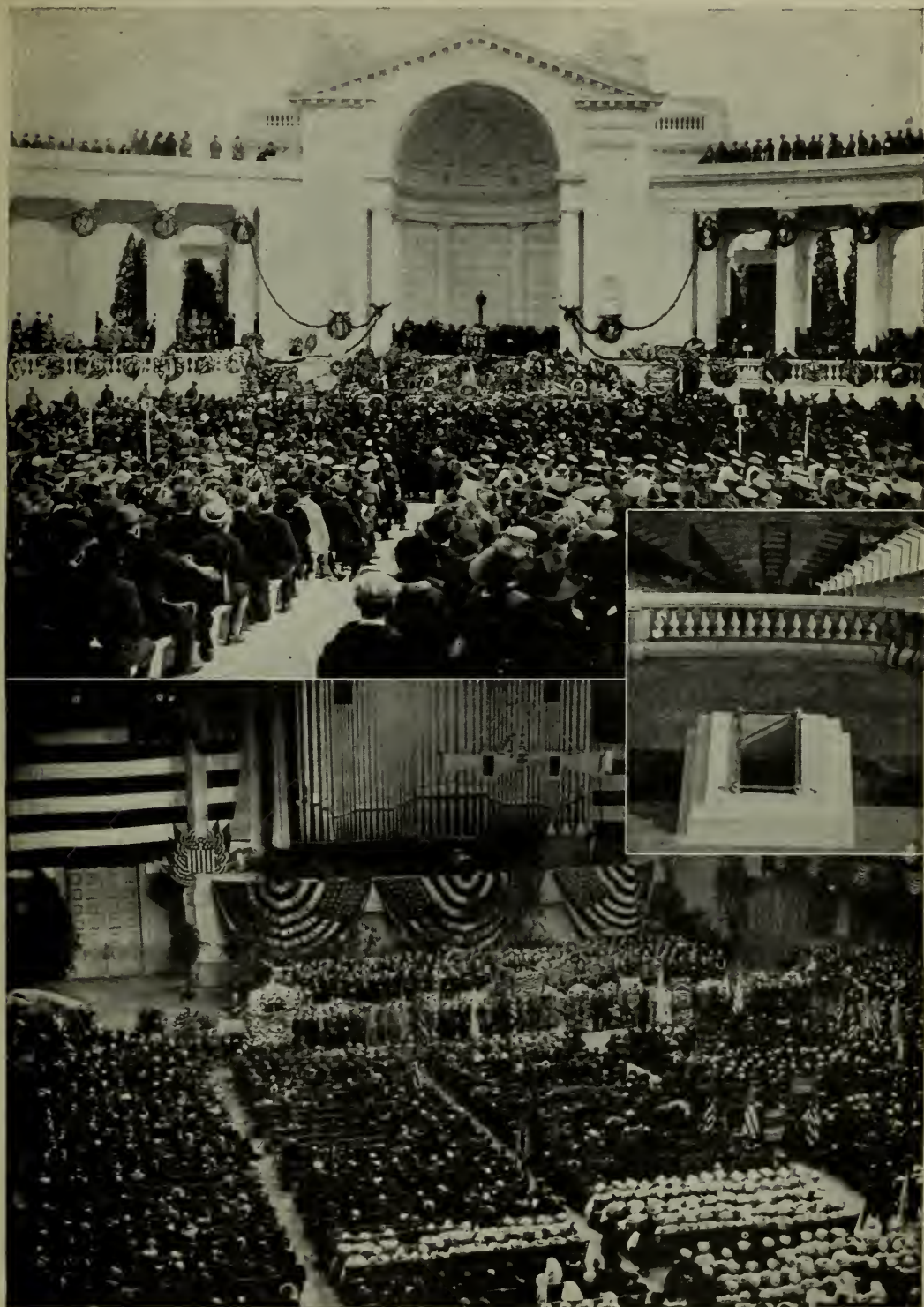
HUGE VOICE AND SOUND AMPLIFYING DEVICE

Strains of music originating in Chicago were transmitted to this amplifier erected at Naponach, N. Y., which intensified the sound waves so that they could be plainly heard from a distance of four miles. This was staged for the benefit of some two score presidents of the country's foremost telephone and telegraph companies.

people may enjoy the health and happiness they deserve.

One might naturally think that the great speed of travel necessary in bringing about this revolution would be attended with terrible danger. What would happen in the case of a collision? Well, the railophone makes collision on a railway impossible. Not only will every train be wirelessly connected with the telephone system

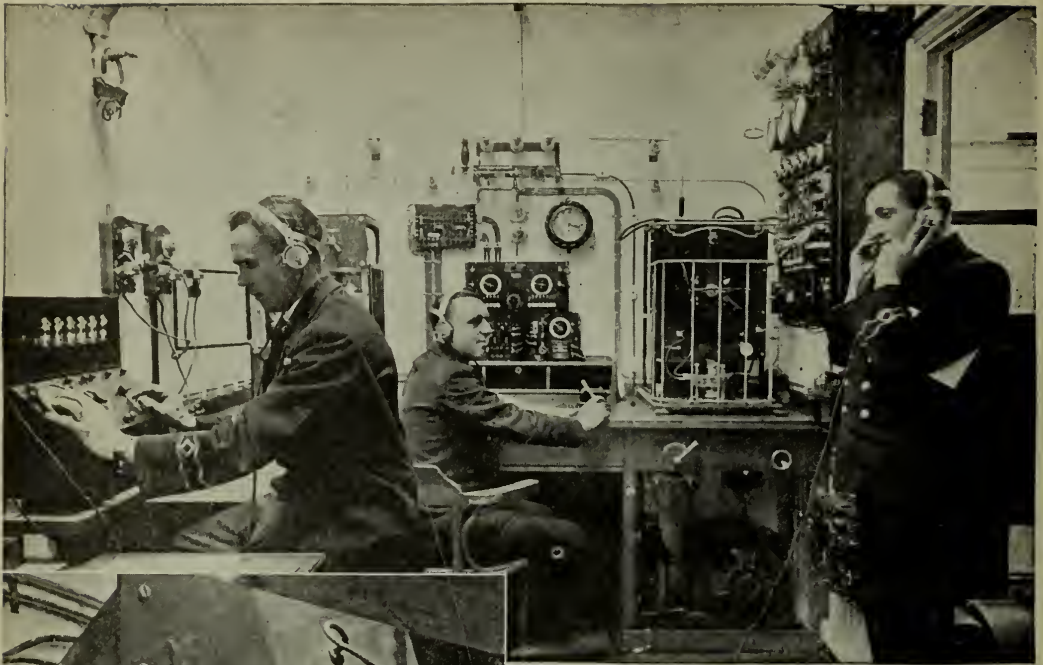
THE PRESIDENT HEARD FROM COAST TO COAST



© Underwood & Underwood, N. Y.

THE PRESIDENT MAKING THE ADDRESS AT THE BURIAL OF THE UNKNOWN SOLDIER AT ARLINGTON

Thousands outside the amphitheater heard his words through the telephone amplifier and the projectors seen in the inset; while below is the audience in the San Francisco auditorium where the same words, transmitted over the long distance wires of the Bell System, were heard by other thousands.



© Ewing Galloway, N. Y.

WORLD'S BIGGEST SHIP'S RADIO ROOM

The wireless room on the *Majestic*. At the left is the Marconi radio compass which determines the exact location of the ship. Next is the large wave transmitter with a 2000-mile range, and, at the right of the man at the key, is the short wave (800-mile range). The large transmitter is a tube set and the short one a spark set. When the ship is carrying a capacity passenger list this well-arranged and costly outfit helps safe-guard the lives of 5100 people by keeping in continuous communication with one shore or the other while crossing the Atlantic. Insert on the left is the tube transmitter of the *Vauban*, which can communicate with stations 1500 miles distant with a power of only $1\frac{1}{2}$ kw.



© Ewing Galloway, N. Y.

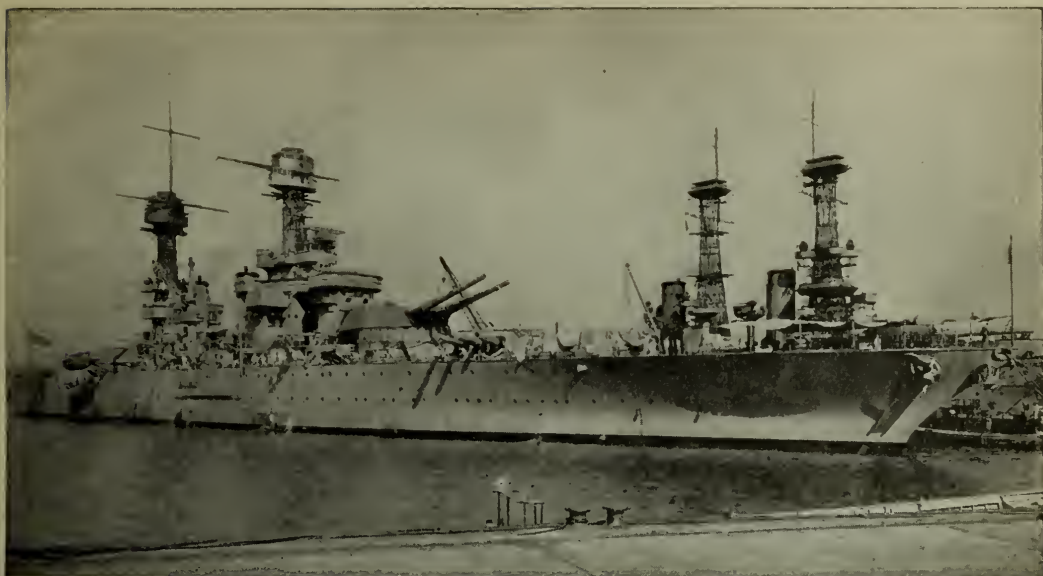
TUBE TRANSMITTER OF THE VAUBAN

but each engine will be linked to all the signal-boxes that it passes; and every train will be in automatic communication with the trains nearing it. When two trains approach so closely as to be in the "danger zone," a wireless telephonic circuit will be set up automatically between them, and bells will ring to warn the engine-

drivers to avoid collision. Moreover, a train which is overtaking another may be stopped dead by a brake action worked by the train in front of it; and any signalman can apply a brake to a train without regard to what the engine-driver is doing.

All these applications of electric power are so numerous, so important, so pregnant with larger results, that we are sometimes inclined to overlook the indirect uses of electricity. Chief among these is the new explosive engine which is becoming a prime mover of incomparable value. By employing an electric spark to ignite some vaporized oil or spirit, a novel and wonderful explosive engine has been invented. Set on four wheels, it becomes an automobile, with a velocity of over one hundred miles an hour; placed on a ship, it forms the "oiler," which is now displacing the steamship; and, fitted with wings, it carries man high in the air, giving him the swiftness of flight and the range of power of the eagle.

ELECTRICALLY DRIVEN SUPER-DREADNAUGHT



CLOSE-UP OF UNCLE SAM'S ELECTRICALLY DRIVEN SUPER-DREADNAUGHT *TENNESSEE*

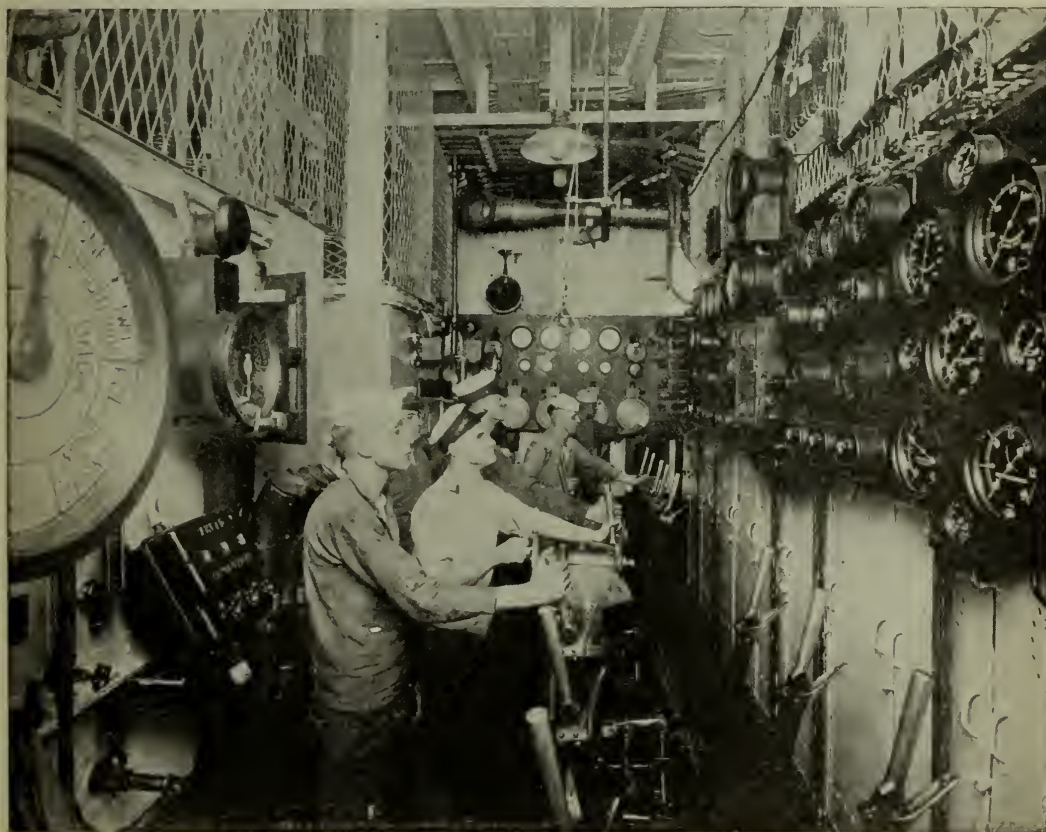


Photo by Ewing Galloway, N. Y.

ELECTRICAL EQUIPMENT IN THE GENERAL CONTROL ROOM OF THE *TENNESSEE*

This is the heart and nerve center of the big warship's machinery, placed in the middle of the ship and protected from shells and torpedoes by heavy armor plate. The few men at the levers control all the electric propelling machinery in accordance with orders electrically communicated from the bridge and registered on the dials in front of them. The *Tennessee* is driven by four 8000-H. P. Westinghouse motors connected to the propellers. Her twelve 14-inch guns are also operated by electricity.

Doubtless, in time, the oil engine — at present one of the most exquisite mechanisms of movement — will in turn be made antiquated by something still smaller but more powerful. It is indeed already possible to divine what will take its place, from experiments made with a new type of explosive engine. In the great petroleum engines used on large motor liners the electric spark is no longer required. The air, instead of being mixed with the oil in the process of vaporization, is first compressed; the compression heats it to a very

inconvenient on an automobile or an aëroplane. What is needed is a far more highly compressed form of fuel than gasoline or alcohol—one worked by the energy liberated by a stream of small, ignited particles of dynamite, nitro-gelatine, nitro-glycerine, or some other modern explosive substance. The two difficulties in the way are the formidable heightening of temperature produced by a single explosion, and the problem of getting varying and relatively moderate movements out of an abrupt and violent source of energy.



Courtesy Canadian Northern Railways

THE TWIN CITIES AT THE HEAD OF THE GREAT LAKES

The cities of Fort William and Port Arthur stand at the great gateway of the granary of the West where Canada's national wealth is transshipped from prairie to market. The thirty huge grain elevators have a total storage capacity of fifty-six million bushels and a handling capacity during the season of five hundred million bushels. The proposed international deep waterways project from the Great Lakes to the Atlantic, utilizing the St. Lawrence River, will reduce freight rates; eliminate transfers, shrinkage and delays; retain identity of shipment, and make these cities the first point of departure without further breaking of bulk of western grain for European ports.

high temperature, and the crude oil is then sent to the cylinder, where the hot compressed air fires it. The oil takes up much less space than coal, the crew is much smaller, there is a great increase in the carrying capacity of the boat, and the terrible working conditions in the depths of an ocean liner are forever abolished.

Even a gasoline tank, however, occupies a great deal of room. It may be much less in size than coal-bunkers, furnace-rooms, and boiler-rooms required in a steam-engine, but it is large enough to be very

How glorious an achievement of the new spirit it would be if the chemist and the engineer, who have armed the nations with the terrible energy of modern explosive weapons, were to transform the power behind the artillery of war into a new force in the industries of peace! The invention of an actual explosive engine, by its concentration of fuel, would revolutionize every mode of travel; and if a cheap explosive material could also be found the end of the age of coal would be very near, with the abolition of the most primitive

and painful forms of human labor now left in use to any considerable extent in the civilized world today.

We have been thinking mostly of the physicist and the inventor and the engineer, but it may be said that the modern chemist is in many respects the supreme magician of our day. He has revived the idea of his ancient predecessor, the alchemist, and shown by actual experiment that the strange dream of the transmutation of the elements was a sober truth. It is to him that we owe the marvelous X-rays and the still more marvelous radium; and more recently he has given us a new element, neon, from which comes a light superior to the radiance of gas and the glow of electricity, and almost equal to clear, soft, steady daylight. He has also discovered for us the wonderful curative rays which are being applied with success in the treatment of disease.

It is remarkable, indeed, what power has been recently derived from modern chemistry. In his laboratories today man can manufacture substances which he was once compelled to extract from living things. He has split up the atom, has seen into this invisible thing, and mapped it out as a system of intricate forces more marvelous in structure and movement than the solar system. At last the chemist has analyzed every element of the material world into combinations of electrical force. To him the universe is made up of two things: centers of electrical force, and a subtle, intangible, all-pervading ether, apparently not subject to gravitation.

Here we come to the ultimate problem in science. Will man ever control the mysterious force which holds in silent equilibrium the solar system on the one hand and the mighty powers in the infinitesimal atom on the other? If we could set loose the immense store of electricity contained in a small pebble we should get an inexhaustible source of power, such as would make us, perhaps, the virtual masters of the universe. It is the last dream of science, and who shall say yet that it is in vain?

The human race is still young. All calculations of the duration of the sun and the life of the earth have been completely upset by the finding of radium. Food will always be abundant, and so will the sources of energy. With so large and firm a foundation, man will surely continue to advance.

Yet there is still one rock on which he may founder. When man has conquered nature, he will be faced with the harder task of conquering himself. Many a nation has been vanquished by its own victories; it has won the means of luxurious life, and then, giving itself up to self-indulgence, has lost at last the manliness of character, the singleness of mind, and the strength of soul which it possessed in the days before it set out on its conquest. In the last analysis, the question of the long future of the human race is a social and religious problem. If it can retain, amid all its triumphs, the spirit of self-sacrifice, the brotherly love, the humility of mind, and the wholesomeness of heart inculcated by the greatest religious teachers, then it will indeed survive.



SCIENCE HAS BROUGHT NEW YORK NEARER TO LONDON THAN YORK WAS IN COACHING DAYS

ALL THE WORLD BUYS AND SELLS



All nations meet at the modern seaport. Here we come into the world's market-place, where Persia is selling rugs, and India is selling jute, and Germany is selling dyes, and China is selling beautiful carvings.

THE CREATOR OF WEALTH

The Vast Traffic between Nations upon
Which the Prosperity of the World Depends

HOW THE WORLD GOES TO MARKET

COMMERCE, the interchange of commodities, is the handmaid of civilization. The science of commerce is the science of the distribution of the world's products among the world's peoples. Upon the effectiveness of the interchange the wealth of the world largely depends.

Wealth may be defined as matter in the right place, as dirt has been defined as matter in the wrong place. It is the supreme function of commerce to create wealth by moving commodities from the places where they can be easily produced, but where often they are useless or of limited use, to places where they cannot be so easily produced, but where they are needed.

We are accustomed to think of the farmer, the miner, and the manufacturer as the real producers of wealth. The trader and the transporting agent seem to us to be concerned merely with the distribution of wealth already produced. We may be forced to admit that their services are necessary, but we think of them as in some way taking toll from the wealth others have produced. A little reflection, however, will show us that such a view of things is wholly false. Neither the farmer nor the manufacturer creates anything really "new." Utilizing the forces of nature, they merely give new forms to things, forms which fit things better for use in the satisfaction of human needs. But it is not alone sufficient that things should be in the form in which they are needed. If a thing is really to constitute an article of wealth, it must be brought to the place at which it is needed and be

available at the time at which it is needed. The creation of wealth, then, involves not only changes in form, but also changes in place and in time.

It is essential that we should see the true significance of commerce as an important part of the process of wealth production and also as the indispensable agent of human progress. The sixteen hundred million people of the world possess much of the wealth they enjoy by virtue of commerce. The progress of mankind — the progress of civilization — may be measured by the progress of commerce. Let us try to look a little farther into these general statements in order that we may see just what they mean.

In the first place, man gains wealth by commerce because the world's natural products are not equally distributed among the different parts of the world. They can be availed of only by exchanging commodities.

It is important to observe that this is true of each nation separately and of the world as a whole. Within the boundaries of the United States, for example, there is the widest variation of natural products and advantages. No other nation has been so richly endowed by nature. But our coal and our iron, our copper, our precious metals, our oil fields, our cotton, wheat, and corn are rarely found in close juxtaposition. They are distributed over wide areas. If our people, like those of the Middle Ages, lived in village communities, with little or no exchange of commodities between different communities, the amount of wealth we could produce would be small indeed. For in

order that there may be wealth there must be markets. Commerce creates markets. It makes the products of any one region available for the rest of the country. It actually creates wealth where otherwise wealth would be almost entirely wanting.

The United States in itself an economic empire

But how much more the creative and fructifying value of commerce becomes apparent when we consider the relation of men living in the United States to the wealth of the world outside its borders. The United States is in itself an economic empire. It is more nearly self-sufficient economically, less dependent on outside sources of supply, than any other country of advanced economic civilization. And yet it is wholly lacking in certain metals, in many valuable woods, in a variety of fibers, in some indispensable miscellaneous articles, such as rubber or coffee or tea, in a number of important vegetable oils, and in various fruits and spices. Without these things the United States might have developed a relatively high economic civilization, but at vastly more toil and cost. It is certain that without our exports and those of other countries richly endowed by nature, the inhabitants of many of the older lands would be condemned to the conditions of an exceedingly primitive civilization, and, it may be added, without them the number of people living in the world would be very much smaller than it is.

Commerce makes us citizens of the world, users of all the world, partakers in every harvest, workers in every field of industry. Not merely material things are thus called into existence by commerce, but lives are conjured into existence by its fruitful streams. Here commerce joins hands with biology. The point is so important that we must give it further consideration.

Why is it that man, alone among living things, is ever multiplying his kind? When we examine the animal world we find that in ordinary course a pair succeeds a pair, and that, while there is a large number of births of each creature in each

region, the number of birds or animals or insects or reptiles in each region remains almost constant. Let us consider the case of the fox. This animal has four or five young at a birth, and it is fruitful for several years. If we imagine a pair of foxes to have merely six young, however, and no more, and that these are divided equally in point of sex, and that the three pairs of young ones each produce six young in the following season, the two foxes have, after the lapse of a year, become multiplied into twenty-six foxes. In ten years at this rate their number would be expressed in six figures. Why, then, does the world not overrun with foxes? The explanation is that the law of nature is a law of death. The number of births is prodigious; the survivals are few. Each region, the woodland, the field, the river, forms an almost self-contained group of lives, in which there is a balance of forces between various creatures preying upon each other. Food is limited; however many are born, only as many can survive as find food.

How man's defiance of nature has changed the conditions of the world

But man rises superior to the order of the nature from which he has emerged. Man is nature's rebel. Where nature says "Die!" man says "I will live." We refuse to submit ourselves to what would appear inexorable law. We till the earth and make a thousand blades of grass grow where one grew before. We produce and add a thousand-fold to the value of our production by interchange with regions we have never seen. Where the fox or the tiger perishes for lack of sustenance, the young of mankind are sustained by supplies artificially created and gained largely by commerce.

The defiance of nature which man exercises on his own behalf is exercised not only in regard to his own kind, but in regard to such plants and animals as he desires for his own purposes to multiply. And, it may be added, in that process of defiant multiplication man multiplies not only what he desires, but what he does not desire. It is difficult for the farmer to realize that he himself, by his kindly pro-

vision of a harvest, has actually created the marauding gophers he detests, and it is even more difficult for man to realize that he himself breeds the organic diseases of his towns.

We see, then, how true it is that commerce is not merely a creator of material wealth, but a veritable creator of population.

The key to the best use of the world which makes men and nations complete

Man gains wealth by commerce, in the second place, because the artificial productions of mankind are exceedingly various in nature and quality, varying with the widely differing gifts of the races of mankind.

Upon the superstructure of natural productions the races of man have reared thousands of arts, and the prime necessity of commerce, which is sufficiently apparent in relation to natural productions, becomes intensified by the remarkable individual and sometimes subtle qualities which the different races contrive to impart to their arts and manufactures. It is only partly true that "all can grow the flowers now, for all have got the seed." Not only as between different nations, but within the borders of the same country, we find the most extraordinary variation of adaptability to the arts, and not merely inequality of production, but indefinable though very real distinctions of form, or texture, or flavor, or fitness for a certain end, which make them desirable. A high form of civilization can only be maintained by the power of access to all the products of all nations, and of all the groups within those nations, and commerce alone can give us that best use of the world which makes the complete nation and the complete man.

But we shall still fall short of seeing the full significance of commerce in modern civilization if we see in it merely an important factor in the world's growth in wealth and in population. The quality of modern living, the structure of our political institutions, the liberties we cherish, are in no small measure the outcome of the growth of commercial enterprise. The typical medieval village was economically self-contained and self-sufficient. It was

economically isolated. Now no isolated community can be wholly free. Robinson Crusoe was not free; or better, perhaps, such a statement means nothing. Liberty is a social fact. It has no meaning except as an aspect of human relations. Isolation, moreover, makes for stability and conservatism, for the hardening of habit and custom into a fixed and rigid scheme of life.

In isolation, as Professor C. H. Cooley has suggested, ideas descend vertically, that is, they come down from the past, transmitted from generation to generation. Thus they are old ideas. With free communication between communities ideas tend more and more to come in sidewise, that is, they come from the outside. They are new ideas. Communities without commerce stagnate.

In the isolated village, with its fixed system of tradition and custom, a man could live his life only by conforming to what custom and tradition required. But when trade developed it brought new contacts, new problems, calling for initiative and energy, giving opportunity and meaning to human freedom. Rightly enough were the early traders called "adventurers."

In the advance of civilization the trader leads the way

Political freedom, as we understand it, appeared first in the towns of the later Middle Ages. These towns were communities of traders. There men found a freedom from the restrictions which obtained in the isolated country villages. There they found new and varied opportunities. Trade between the towns became world trade in the modern sense after the discovery of America and of the sea route to India at the end of the fifteenth century. In the advance of civilization into the new worlds thus opened up, the trader, along with the missionary, led the way.

Doubtless economic civilization today remains far short of its goal of equality of opportunity for all. But it is important for us to remember that such a goal could not be conceived of, even as a remote ideal,

by the men of antiquity or of the Middle Ages. Freedom of commercial enterprise has brought with it enlarged and enriched notions of the meaning and significance of liberty. That the world now ranks men according to their own achievements and only in small measure by the status into which they were born is to be attributed in no small measure to the fact that commerce and the system of free enterprise that has grown up along with and as a part of commerce gives little weight to anything but achievement and success.

How the Law Merchant differed in spirit from other systems prevalent

An illustration of the significance of the relation of the growth of commerce to the growth of freedom is found in the history of the Law Merchant. This was in the beginning merely a body of rules laid down by medieval merchants for regulating their relations one with another. The old rules of medieval law hampered them. Moreover, their trade created new situations and problems to which the old rules did not apply. The Law Merchant was different in spirit from the then prevailing systems of law. It made little of distinctions of outward form, of the status of the parties to a litigation, of title or sex, in order that it might deal with rights and duties on a broadly human basis. It had to do very largely with contract, that is, with free agreement. It has long been absorbed into the general body of our law, where it has had a most wholesome influence and effect.

Quite in keeping with what we have seen to be the general character of free commercial activity is the fact that in the growth of our economic civilization it has been commerce, rather than agriculture or industry, that has led the way. Production is limited by the market. It can advance only as markets are increased. Commerce creates markets. The industrial revolution at the end of the eighteenth century, when the factory system came into being and when the use of power was first successfully applied to manufactures, cannot be ascribed merely to the great

inventions of Watt, Kay, Hargreave, Arkwright, and Crompton. These mechanical improvements were, from one point of view, really called into being by the fact that the growth of English commerce, and especially the development of the Indian market, had, for the first time, made the factory system and large-scale production possible.

Men do not produce or manufacture goods in the blind hope that in some way buyers will be found. In manufacturing and agriculture alike production increases only when larger markets are available. The history of commerce has been the history of the growth of markets. Markets can grow either extensively or intensively. One sort of growth is a broadening of the territory which affords the market to the commerce of the nation; the other sort of growth is bound up with the creation of new wants and new standards of living. It is commerce more than anything else that has given men new wants. The status of economic civilization is determined by the number, character, and quality of the wants which constitute a people's standard of living. Just so far as commerce has taught men to know and to want more things and better things, just so far it has been the moving force in the progress of economic civilization.

Commerce ever a spur to the sciences connected with transport

Distribution rests upon means of transport and locomotion, and commerce, therefore, has ever been circumscribed by the limitations of other sciences. Commerce is the debtor of the engineer and the scientist, but the stimulation of commerce has ever been a spur to the sciences connected with transport. In ancient days it was the economic stimulus which impelled Nebuchadnezzar to the construction of a mighty ship canal from Babylon to the mouth of the Euphrates on the Persian Gulf. In modern times it was the economic stimulus which called the steam-engine into being. The necessity of pumping water out of British coal-mines mothered first the crude steam-engine of Newcomen, and led to the inventions

and discoveries of Watt, Stephenson, and Brunel, who, by increasing transport facilities a thousand-fold, made modern commerce possible. The possibility of large-scale and rapid transport has, in the last half-century, brought the ends of the world together, caused an unprecedented production and consumption of wealth, and quickly created a new order of economic problems of which the solution may still be in doubt.

The four conditions upon which the trade of nations rests

The main conditions of commerce now appear. They are four.

1. The combination of trust and confidence which we call Credit.

This factor was slow of growth. In the history of man the establishment of banking by the Italians is as yesterday, but the space from the beginning of man to the establishment of the exchange on the Rialto is a matter of ages. Today trust is so far the rule that perhaps there was never a time when a man without scruple could more easily find victims. We are so accustomed to credit that its failure here and there is but the exception which proves the rule of honor.

2. Easy and cheap systems of Transportation and Communication.

The marvelous work of the engineer has been a magnificent contribution to the means of commerce. The Romans built roads for all time, but the modern engineer has given roads a new meaning, and solved problems which might have saved the Roman Empire. The canalized river, the artificial waterway, the railroad, and the steamship have, in the last eighty years, made it possible to use the world commercially as it was never used before. New wonders of the world have appeared in the Panama Canal, in the giant steamship, in radio telegraphy, in aerial transportation. The natural resources of the world are being tapped at a prodigious rate, and it is already becoming apparent that a greater unity of the sciences is needed if man is to increase the interchange of the supplies upon which his civilization depends.

3. Security for the Trader.

In medieval times the merchant "suffered even more," as Professor Clive Day has put it, "from bad men than from bad roads." Government was weak; traders were often strangers, and strangers were suspect. There was an old English law, "If a man come from afar, or a stranger, go out of the highway, and he then neither shout nor blow a horn, he is to be accounted a thief, either to be slain or to be redeemed."

Now, save in time of war, every civilized country undertakes to give full and adequate protection to the trade and the traders of other countries. For the most part these undertakings are embodied in commercial treaties between different nations. A feature very commonly found in commercial treaties is the "most-favored nation clause," by which each party to the treaty undertakes not to discriminate against the trade or the traders of the other party. A nation often binds itself to give the traders of other nations as favorable treatment in some respects and as adequate protection as it gives its own citizens.

A very important and interesting development of the principle of the commercial treaty is found in a number of multilateral treaties or conventions which are designed to prevent different forms of unfair international commercial competition. It is in this way that international protection is given to such valuable commercial rights as patents, trade-marks, firm names, and brands.

The modern trader thus has back of him the countenance and support of his own government and the protection of the governments of the other nations with which he trades.

4. An effective machinery of Exchange.

Man has passed from crude forms of exchange to a marketing conducted by credit instruments. Existing processes have been so far perfected that almost every known commodity is easily procurable in the world's great centers of population. It is nevertheless true that the science of commerce, regarded properly as the science of distribution, is far less

advanced than the science of production. In this twentieth century of our era we find it a much simpler matter to produce cloth, or furniture, or apparel than to secure by commerce a full supply of these things for all those who desire them. Here the problems of commerce join hands with those of sociology.

A function of commerce which looks to statesmen for guidance

We may be well assured that in relation to all these essentials of commerce man is destined to make enormous progress. An increasing standard of life in all countries will breed an ever-growing confidence of man in his fellow men. International relations will improve through the better knowledge which casts out fear and suspicion, and through the increased interdependence of trading communities. The engineer and the scientist will continue the task of perfecting the links of communica-

tion and the powers of production, so that an ever-increasing volume of commodities will pour along the great trade routes.

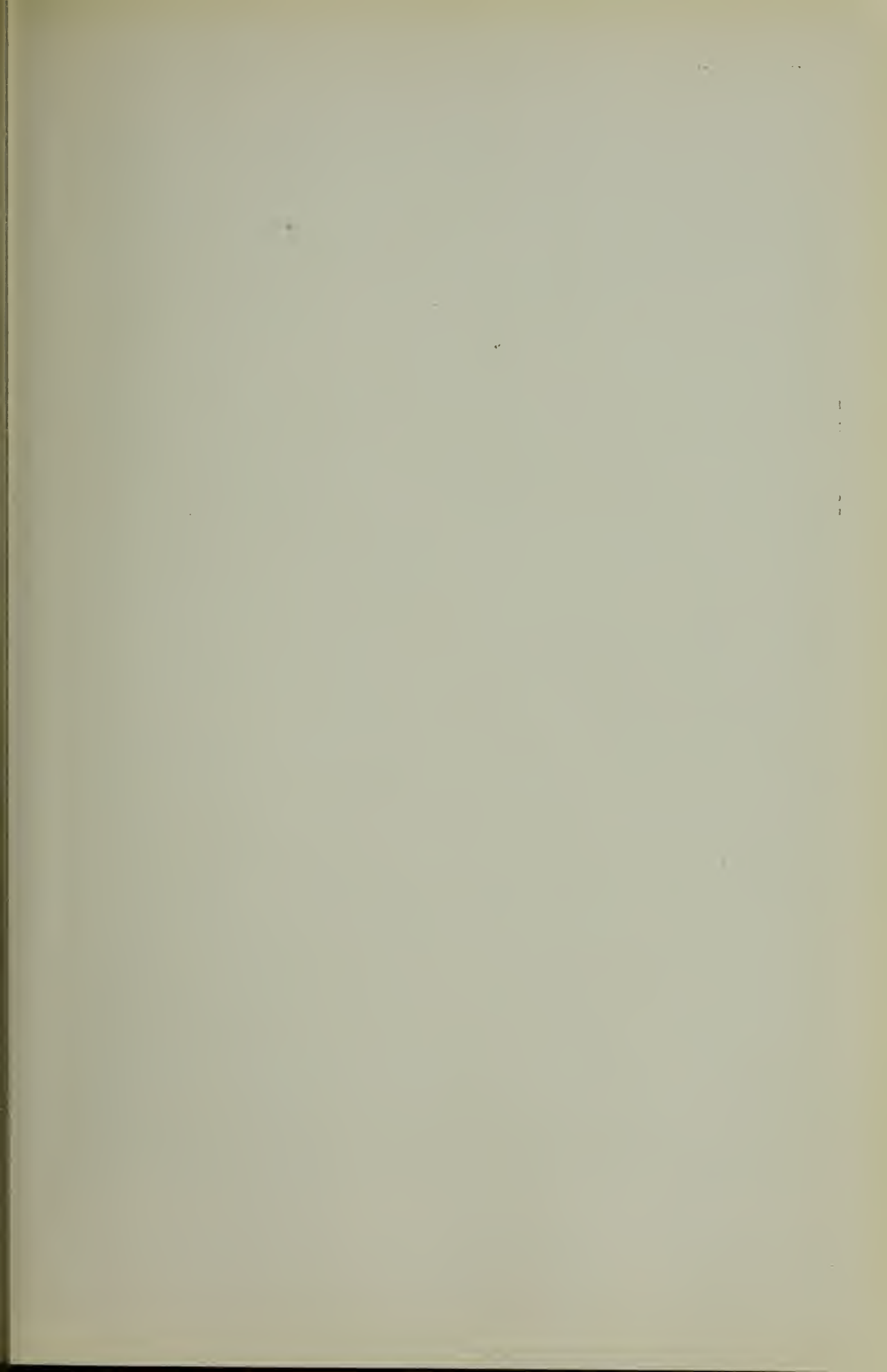
Finally, the combined efforts of the merchant, the economist, and the statesman will enable the world to come to market in a sense transcending the commerce of today. Commerce, which already has high functions, will come to be universally recognized as a matter of the first importance, demanding the application of the highest faculties of the most gifted men. The ancient and ignorant contempt of the "gentleman" for the votaries of trade has already, in great measure, disappeared. The organization of the production and distribution of wealth, perhaps in forms and by methods of which we have yet small conception, will come to be properly regarded as one of the chief functions of civilization — a function which will look to every science for aid and to every statesman for guidance.



Photo from Wide World Photos

COMMERCE EVER A SPUR TO THE SCIENCES CONNECTED WITH TRANSPORT

The *Majestic*, the largest steamship in the world, passing lower Manhattan on her way to her berth, after her maiden voyage.



THE PENT-UP ENERGY OF AGES AND AGES



© Kohlmann

MOUTH OF AN OIL WELL AT COMODORO RIVADAVIA, ARGENTINA

It often happens that oil shoots out of the earth with tremendous force, driven out by the gas which has been pent up with it for thousands of years, and millions of gallons run to waste in this way. Men with leather suits and metal helmets fix steel caps over these gushers when at last they can be controlled.

LIFE IN THE GREAT OIL FIELDS

The Universal Power Pent up for Ages and
Ages down in the Depths of the Earth

THE MINERAL OF THE MODERN WORLD

WE can easily picture what the world was like before the days of railroads. Many of us can quite well remember the days before we had the electric light and the telephone. A world without electricity at all is not so very hard to imagine; but a world without mineral oil, without petroleum—try to imagine that!

Perhaps you think this is not so difficult. In that case you have clearly no conception of the many uses to which petroleum is put. Only a small quantity of the whole production is employed to give light. Abolish mineral-oil lamps, and the petroleum mining industry would go on almost as vigorously as it does now.

Petroleum would still be used for making gas, for making paraffin-wax candles, for making electric-light carbons. It would still be necessary, in the form of lubricating oils, for keeping in order the machinery upon which the modern world depends. It would still be the motive power for automobiles, gasoline engines, and flying-machines.

It is petroleum which has made flying possible. No form of motive power but the petrol engine was light enough to be carried in the air. Here is its greatest achievement. At the other end of the scale of utility it supplies us with perfumes and cosmetics. In between come a multitude of uses. It gives us asphalt paving, permanent ink for printing, dyes of brilliant hue. It gives us aluminum, the production of which depends upon petroleum. It gives us rubber tires and all kinds of rubber articles which, without petroleum, could not be manufactured.

Strange, then, seeing how much use we all make of petroleum and its products in our daily lives, that it is only just over half a century since this mysterious oil began to be extracted in any large quantity from the bowels of the earth, where it is formed, in all probability, out of decaying animal and vegetable remains. In 1859 the first well in the United States was drilled by Colonel Drake. Up to that time mineral oil had been collected by means more or less casual. Thenceforward the mining of petroleum became a science. It also became one of the largest industries in the world.

Very soon the regions where oil was known to exist began to be "prospected." In some places shepherds had been in the habit of driving their flocks to pools of oil, and lighting the oil for warmth. In the Caucasus there was a Parsee shrine where a flame had been alight since before the birth of Jesus. It was a place of pilgrimage for fire-worshippers. In Galicia and Roumania old books told where oil had been taken out of the earth for centuries. The great mineral of the modern world had been tapped by men who could not have had any conception of its power.

The principal oil fields from which the world draws its supply of petroleum are in the United States, Russia, Roumania, Austria-Hungary, East Indian Islands, and Burma. Other countries where deposits are being worked are Mexico, Peru, Assam, Japan, Germany, the West Indies, and Persia. When the known deposits are exhausted, there will remain immense areas yet untouched where oil certainly exists; so that there is no likelihood of

the supply of petroleum failing for many centuries to come. The amount at present taken out of the earth is over a million tons a week. In fact, more than that has been so taken in the United States alone.

It was not known at first that petroleum could be used for lighting. Upon the discovery of this followed hard its employment in other ways. The practical business minds of the United States set to work to make the most of the addition to the wealth of the country. Scientific men also contributed to the development of the industry. Several famous chemists devoted themselves to the study of petroleum, among them Mendeléeff, Sir Boverton Redwood, Lissenko, Engler, Beilstein. They are not yet agreed as to its precise origin. Mendeléeff, for instance, thinks that it was formed by the action of water on molten or heated metallic carbides. Engler maintains that it must be due to the liquefaction of animal remains: he has actually exhibited products, exactly similar to those of petroleum, which he had made from animal fats. Another chemist, C. M. Warren, has obtained synthetic oil through distillation of fish and other organic matter.

Equally valuable, and perhaps of more immediate practical use, has been the work of the geologists who have studied the formation of oil fields. This branch of knowledge may be still incomplete, but enough is known to prove of great assistance to prospectors. It is now accepted, for example, that petroleum is always found in a series of "pools" which are really saturated portions of stratified rocks, usually sandstones, and closely associated with arches in the rocks.

A discovery that has made fresh openings for men of brains

The geologist recognizes the kinds of rocks that may contain oil, and although the arches do not coincide with surface elevations, he can, nevertheless, by a careful study of the slopes of the strata, determine the most favorable locations for drilling.

Thus, while the discovery of petroleum as an industrial product has given the poor, who before could scarcely ever afford

to use artificial light in their homes, a cheap and bright illuminant, and while it has at the same time provided the world with a new motive power, it has also brought into being new activities of science, and offered fresh openings to men of ability and brains. "There are few branches of engineering," says Mr. A. Beeby Thompson in his textbook on the subject, "that offer brighter prospects to an energetic and enterprising engineer, and there is certainly none that presents more varied and interesting problems."

A vast amount of capital is employed in oil-mining, and in recent years a large number of new wells have been drilled in search of oil and gas. Many of these have proved to be "dry holes" — that is to say, no oil has been found by them; but, on the whole, considerable good has been done, as rock formations that had not previously been pierced have been thoroughly explored, with frequent discoveries of profitable oil-pools. Many rocks have not yet been prospected, and plenty of chances for profitable discovery still remain.

A vast business which may yet be only at its beginning

There is undoubtedly money to be made by sensible investment, for the consumption of petroleum and its products is increasing, and seems likely to continue to increase, especially when liquid fuel comes more generally into use. There are many, indeed, who think we are only at the beginning of the industry even now.

Here are some figures showing the enormous increase in the production of petroleum from 1878 to 1908:

	METRIC TONS		METRIC TONS
1878 . .	2,077,291	1908 . .	38,052,000
1898 . .	16,381,060	1920 . .	98,600,000

During the 'eighties and 'nineties the United States and Russia kept fairly level in their output. During this century the American oil fields have increased their production very largely and left the Russian oil fields far behind. Meanwhile, Roumania and Galicia are gradually creeping up though their quantities are trifling compared with those of the two great oil-producing countries.

WHAT THE OIL FIELDS LOOK LIKE



At first sight an oil field looks like a forest blackened and charred by fire. Above every well is a derrick, constructed of wood or steel, and usually of a black and dilapidated appearance, though sound enough to support the strain of the huge tools let down into the well.

Oil is found in rather distinct regions or areas, called "fields." In the United States there are ten oil fields, as follows:

1. Appalachian, extending from New York to Alabama.
2. Ohio-Indiana.
3. Illinois.
4. Mid-Continental, in Kansas and Oklahoma.
5. Gulf, in Louisiana and Texas.
6. California.
7. Colorado.
8. Michigan.
9. Wyoming.
10. Alaska.

The Appalachian field is the largest in proved area, but the greatest production of oil comes from the Mid-Continental and California fields. It is the oil from Pennsylvania which commands the highest price as it is quite free from objectional impurities, and yields, by the ordinary mining methods, the highest percentages of gasoline and illuminating oil—the products in greatest market demand.

At first sight an oil field looks like a forest blackened and charred by fire. Above every well is, an erection called a derrick, constructed of wooden timbers, or steel beams. These are mostly of a black and dilapidated appearance. They are sound enough in reality, or they would not support the strain of the huge tools and "balers" that are let down into the wells.

But they look very hideous and ruined when seen from a distance.

Nor is this first impression of dirt and dreariness wiped out on closer inspection. Among the derricks there are mud pools everywhere—slimy, viscous, horrible. Masses of iron piping lie about, heaps of spare implements. There are no roads, only tracks. Take care that you do not

step into an oil pond or trip over a pipe-line.

We stop for a few minutes at the door of a derrick. They are hauling up a drill with which they have been deepening the well. One of the workmen says something sharply, and motions us to stand back. Too late! Out comes the drill with a sputter of oily mud all over us.

The first thing to do when the existence of oil has been discovered is to make a hole through which it can be got out. The hole is made first with instruments called "spuds," and finished with



From Bacon & Hamor's "American Petroleum Industry," McGraw-Hill Book Co.
THE DRAKE WELL, AT TITUSVILLE, PA.

Drilled in 1859 by Col. Edwin L. Drake, this was the first oil well in America. A monument to the memory of the founder of the petroleum industry, "the friend of man," was erected in Titusville by the late Henry H. Rogers of the Standard Oil Co., himself a pioneer in the Pennsylvania oil fields in the 'sixties.

powerful drills. As the shaft is sunk it is cased in with iron tubes, which are let down from the top. As the work proceeds, smaller tubes are placed inside the first ones, and smaller drills are used. Then the space between the tubes must be filled up. Every care has to be taken to keep the sides of the well solid and water-tight. When the oil is drawn up mixed with any

HOW OIL COMES UP FROM THE EARTH



The hole through which oil comes up from the earth is cased in with iron tubes, which are smaller as they reach the bottom ; and through this iron shaft, which may be anything from 500 to 4000 feet deep, the oil is brought up in various ways. This picture shows the usual way of bringing up oil by pumping.

THE TERROR OF FIRE IN AN OIL FIELD



The sight of an oil field with a spouter alight, with derricks burning and brooks of oil carrying hither and thither sheets of flame, with vast volumes of black smoke darkening the sky, might well inspire an artist with the imagination of a Gustave Doré to paint a picture of the end of the world. The best

LIKE A SCENE OF THE END OF A WORLD



way of putting out such a fire is to inject steam into it, and this is very often done. Among the other ways of extinguishing these fires are to drag a tremendous weight of steel rods over them, or to run an enormous iron cap along the rails, dropping the cap over the flame as a snuffer is dropped over a candle.

considerable quantity of water, its value is very much diminished. Oil and water must be separated, and the cost of production is thereby largely increased.

By a cable from two to two and a half inches in diameter a string of tools is lowered into the well. These tools are screwed together with a great deal of force, so that no blows in the well shall cause them to come apart. When tools are lost in a well they have to be fished for. Special "grabs" and "spears" have been invented for this purpose, but it is often a long time before missing implements can be found. Sometimes an impression has to be taken of the bottom and sides of the well to discover where they are.

The men who bring up the huge baler that dips down into the well

The drill falls at the rate of from twenty to forty strokes a minute, according to the nature of the soil. Now they are stopping it. It is hauled up, and a cleaner is substituted for it, to take out the pulverized earth. The cleaner has on its lower end a valve that opens inward and allows the debris to enter. When it is full, the valve automatically closes, and the cleaner goes up to be emptied. When there is a great deal of sand or thick stuff in the well, a "sand-pump" is used. This is a cleaner with a piston inside it, drawing up through the valve the stuff which is not light and loose enough to enter freely.

The well having been sunk to the required depth, which may be anything from 500 up to 4000 feet, the next proceeding is to get the oil out. There are various ways of doing this. The most usual in the United States is pumping. Where this is possible, it is the cheapest and most efficient. The oil, when pumped up to the surface, is received in a reservoir or carried off by a pipe-line to some central storage tank. That is simple enough.

There are some oil fields, however, where so much sand comes up with the oil that pumps cannot raise it. Then valves and plungers are soon put out of action. Here the oil is got up by means of a "baler," a huge tube fifty or sixty feet long. This

is lowered into the well. It is filled by the action of a valve opening inward, as in the cleaner; and then it is hauled up and the oil is discharged into a "baling tub" where the sand is allowed to settle before the oil goes into the tank.

Perhaps, however, the oil may not have flowed freely as soon as the oil-bearing layer was drilled into, and it may have been necessary to "shoot" the well before pumping or baling. This scheme is often used where the oil-rock seems to need shattering, that it may readily give up the oil with which it is soaked. A "torpedo" is lowered down the drill-hole by means of a wire. The torpedo consists of a tin tube, 4 or 5 inches in diameter, from 5 to 20 feet long, and containing from 20 to 90 quarts of nitroglycerin. In its cover is a percussion cap, the explosion of which will set off the nitroglycerin. It is lowered with the greatest of care, until it is in the oil-sand, when there is dropped upon it a weight, called a "go-devil," which strikes the cap and thereby explodes the main charge of the torpedo. The explosion may have taken place many hundred feet down in the earth, and a rush of oil, smoke, and gas may be the only effect seen at the surface, but the work has been done, the oil-sand shattered, and from that time on the oil flows much more freely. Not only are new wells torpedoed, but also the lives of old, declining wells are often prolonged by means of this very simple procedure.

Another operation at the well seems marvelous. There is a continuous flow of oil into a tank outside a derrick, with nothing to show how it is being brought up. There is no wire, no one about, no visible agency. All that we see are a couple of pipes, one going down, the other coming up out of the well. Now, the pipe that goes down is charged with compressed air. This compressed air forces the oil up the other pipe, and so into the tank. It is quite simple, after all.

There is a point to notice about that compressed air before we leave it. It is compressed by gas engines, which are fed by the gas from the wells. Wherever petroleum is, there is also natural gas. A great deal of it is wasted — most of it,

in fact — but here it is being made use of. It is sucked out of the wells into gasometers, thence it is fed to motors and also to the boiler-houses, which provide the power for the well engines. See what clean, clear, roaring fires it makes! Some of them are oil fires. In time oil fuel may perhaps supersede coal altogether. No more filthy stoking in a scarcely endurable atmosphere! No more gangs of half-naked shovelers, dripping and gasping in the stokeholds! Only a mechanic or two, clean and cool, turning a tap every now and then to regulate the spray of oil which feeds the hot blaze.



AFTER BEING "SHOT"

Another method of raising the oil from the wells is the air-lift process. This is quite distinct from the compressed air plan. It does not force the oil up, but, by aerating it, causes it to flow gently in a constant stream to the surface. A fifth system has in the last few years been invented by an Austrian engineer. This sends down into the well a specially made endless band which absorbs the oil. When it comes to the surface, it is squeezed between rollers, the oil drops off into a conduit, and the band pursues its way downward to be once more passed through the oil again. The advantages and disadvantages of the system are obvious.

All these methods are for use when the flow of oil has been got well under control. It often happens that at first the oil shoots out of the earth with tremendous force of its own accord; or, rather, it is forced out by the gas which has been pent up with it for hundreds of thousands of years, perhaps, and which has been known to create a flow of 170,000 barrels in a single day. Generally, probably due to the weight of overlying strata, the pressure of the gas is proportionate to the depth of the drilling. In these cases, as soon as the drill pierces the oil deposit, there is an upward rush, and, unless precautions

have been taken to control it, enormous quantities of oil are wasted. These rushes of oil are called "spouters" or "gushers." They rise to a great height, and, if one is watching them, it is necessary also to watch the wind, and to keep carefully to windward of the spouting oil.

In some cases, notably in Mexico, the flow seems to be caused by



COMPLETED WELL IN TEXAS READY TO BE "SHOT"

the action of water. Here the formations are very porous, opposing little obstacle to the flow of the oil. The production from the wells is very great and, unlike most wells, a gradual decline in the yield is unusual, there being little sign of exhaustion until the moment when the well begins producing salt water in increasing proportions.

The escape of the gas pent up for hundreds of thousands of years

Sometimes a gusher continues a long time. One at Baku lasted eighteen months. This was not a violent flow expelled by gas, however. It was steady, and the cause of it was the dissolution in

the petroleum of gaseous hydro-carbons. This reduced the weight of the column of liquid — having the same effect, in fact, as the aëration — and accounted for the discharge. At Grosny, in the Caucasus, an unfortunate Englishman struck a spouter, and thought he had made his fortune. But he could not control it. The oil ran away downhill. It killed sheep and spoiled pasture, and farmers began putting in claims for compensation. The

owner of the spouter would have paid handsomely for the flow of oil to be stopped, but nothing could stop it, and he was ruined.

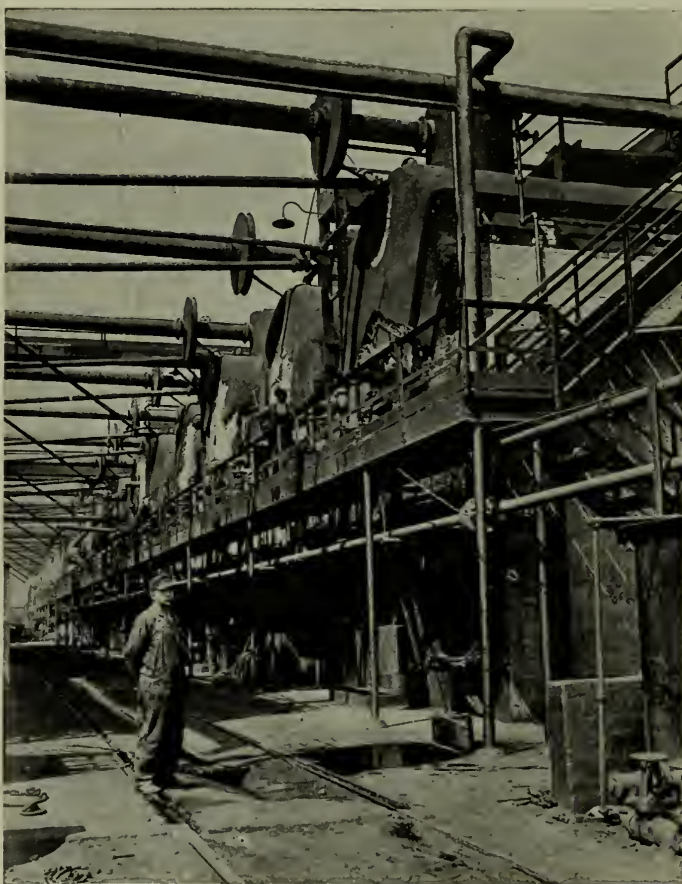
The usual method of controlling a powerful discharge of oil is to have a "casing head" at the top of the well, fitted with strong valves, through which the oil can be led away into a reservoir. But it often happens that the discharge is too violent to be tamed in this way, especially when

there is much sand with the oil. Even a pressure of 500 lbs. to a square inch has failed to keep a gusher down. Cast iron or steel valves have been cut to pieces. Casings have been burst asunder by the tremendous force of the oil. In many Caucasian oil fields it is usual to fix a heavy steel or cast iron shield about eighteen

or twenty feet above the mouth of the well, to prevent the column of oil from being blown about, and so lost. Even these shields have been utterly destroyed, however, by the stones and sand shot up with the petroleum.

A great danger when a spouter has been struck is the possibility of its catching fire. The sight of an oil field with a spouter alight, with other derricks burning and brooks of oil carrying hither and thither sheets

of flame, with vast volumes of black smoke darkening the sky, might well inspire an artist with the imagination of a Wiertz or a Gustave Doré to paint a picture of the end of the world. The best way of putting such a fire out is to inject steam into it. To do so, a number of pipes are coupled to a high-pressure boiler, and at a given moment they are all turned on to the flame. The steam prevents air from getting to it, and without air it dies.



© Ewing Galloway, N. Y.

HUGE OIL STILLS IN THE SINCLAIR REFINERY AT EAST CHICAGO

About 20 per cent of the crude oil output in this country is used for gasoline. The annual production is about 400 million barrels. In a few years the rate of consumption will be half a billion barrels and if the government estimate is true, that only about six billion remain to be mined, we shall soon be buying oil abroad.

THE PIPES THROUGH WHICH OIL RUNS



OIL GUSHER UNDER CONTROL, SPOUTING FROM A BIG PIPE INTO A LAKE RESERVOIR



AN IMPRESSIVE ARRAY OF PIPES THROUGH WHICH OIL FLOWS ON ITS WAY TO THE REFINERY



ONE OF THE GREATEST OIL RESERVOIRS IN THE WORLD, HOLDING A MILLION BARRELS



AN OIL-WELL WHICH FORMED A LAKE, THE STREAM ON THE RIGHT BEING ONE OF A DOZEN

Now we have seen how the oil is extracted from the bowels of the earth. But, as it comes up, it is fit for very few uses. Almost all of it has to go through the process of being refined before it is good for anything at all. According as it is refined, it becomes lamp oil, lubricating oil, or liquid fuel. It goes into the refinery a thick, brown, sludgy substance, oozing along, and smelling strongly of gas. It may come out perfectly white and almost odorless. That is the most highly refined product. From that downward we have a scale of oils until we come to the thick residue, used for liquid fuel.

The oil that lights the lantern and darkens the face of the earth

An oil field is not a pleasant place, as we have seen. It is exceedingly interesting to visit, but one would not choose to spend a holiday there. Still less, however, would one care to pass any more time than one can help in an oil-refinery. At Baku they call the quarter where the big refineries are Black Town. It would be impossible to find a better name. Everything is black — roads, walls, chimneys. Columns of smoke do their best to blacken even the sky. As we go into New York Harbor we see far away over to our left, on a spit of land, the chimneys of the Standard Oil refineries, making a dirty patch upon the blue horizon. There seems to be something in the nature of the industry which causes it to form blots upon the fair surface of the world, wherever it is carried on. Think of the contrast of these places with the myriad bright, clean homes the product lights. It is that between the fertilizer and the resultant flower.

The oil leaves the refinery and is ready for the market

All the same, notwithstanding its depressing ugliness and filth, an oil refinery is full of interest for the inquiring mind. Look at that row of stills, for instance. Nothing much of an appearance, certainly; but in those stills the process of refining the oil is going on. This is the way of it. First the oil is superheated, then it passes through an instrument called a "deflegmator." Its various components are separated. It is turned into vapor, then it is condensed back again into liquid. The stills vary in heat. At first only oils of low density are formed. As the temperature rises, denser distillates are expelled and condensed. So from one process quite a number of different oils are produced.

In a shed close by there are many taps and tanks. Here the different oils flow. Now one can detect variations of color and smell; but the oils are not yet ready for use. They have to be treated still further, first with sulphuric acid, and next with caustic soda. The sulphuric acid absorbs the constituents of the oil which contaminate it, but at the same time leaves a good deal of acidity in it. The caustic soda removes that acidity, and further cleans the oil. Then it passes into a settling tank, after which it is ready for market. As a rule, however, the market is a long way off, and difficult to get at. Oil is an awkward commodity to handle, and it must be handled in large quantities. It was the cost and the inconvenience of sending it in barrels over bad roads on wagons which made American oil-miners think of passing it through pipes.

THE OIL ON ITS WAY ROUND THE WORLD



A QUAIN BOAT ON THE HOOGLY RIVER IN INDIA, WITH OIL FOR THE CITIES ON THE GANGES



THE MOST PRIMITIVE FORM OF DISTRIBUTION
Filling a lamp direct from the cart in Japan.



MODERN DISTRIBUTION IN EUROPE
Pumping oil from a street tank.



DONKEY CARAVANS CARRYING OIL FROM THE SEAPORTS TO THE TOWNS OF NORTH AFRICA

It is hard to think of a world without oil, almost the only mineral product which finds its way to every corner of the earth. These pictures show some of the ways in which the oil reaches its destination.



THE TANK STEAMER, OFTEN CARRYING A LOAD OF 14,000 TONS OF OIL ACROSS THE SEA

The distribution of the oil to all parts of the world

The first pipe-line was made in 1865, and ten years more passed before a trunk line was laid down, in Pennsylvania.

Now pipe-lines are common. The Appalachian field is connected by pipe-line with many cities of the northern and eastern states. Lines run from Oklahoma and Kansas to cities on the Gulf of Mexico, and also eastward through Missouri, Illinois, Indiana, Ohio, and Pennsylvania to the Atlantic, while a third line takes an almost straight course to Chicago, and in the fields themselves a veritable network may be found.

Of course, these pipe-lines need to be laid with great skill and care. There must be no weak places where leakages may occur. The pumping stations must be well equipped and kept in good order. It used to be necessary, too, to guard lines

against the attacks of teamsters who had lost the carrying of the oil. It was difficult not to feel some sympathy with them, as with all workers who suffer through ingenious machinery doing their work; but against the hardship to a few must be set off the benefit to the many who could buy their oil at a lower price as the result of cheap and quick conveyance.

Another change of equal importance was made when the practice of shipping petroleum in barrels was given up. This was both clumsy and expensive. It required a great deal of labor, and the barrels often cost more than the oil they contained. Some other means of transit had therefore to be devised, and the invention which superseded barreling was the tank steamer. The first was used on the Caspian Sea to carry the oil from the Baku fields over to the mouth of the Volga. Soon ocean steamers were built which could be filled direct from pipes, and now tank-ships are



TRAIN OF TANK CARS RUSHING OIL TO NORTHERN ORCHARDS TO SAVE THE FRUIT



From Victor Ross' *Evolution of The Oil Industry*

PIPE LINES FOR LOADING OIL ON VESSELS ANCHORED ONE OR TWO MILES OFF SHORE (MEXICO)

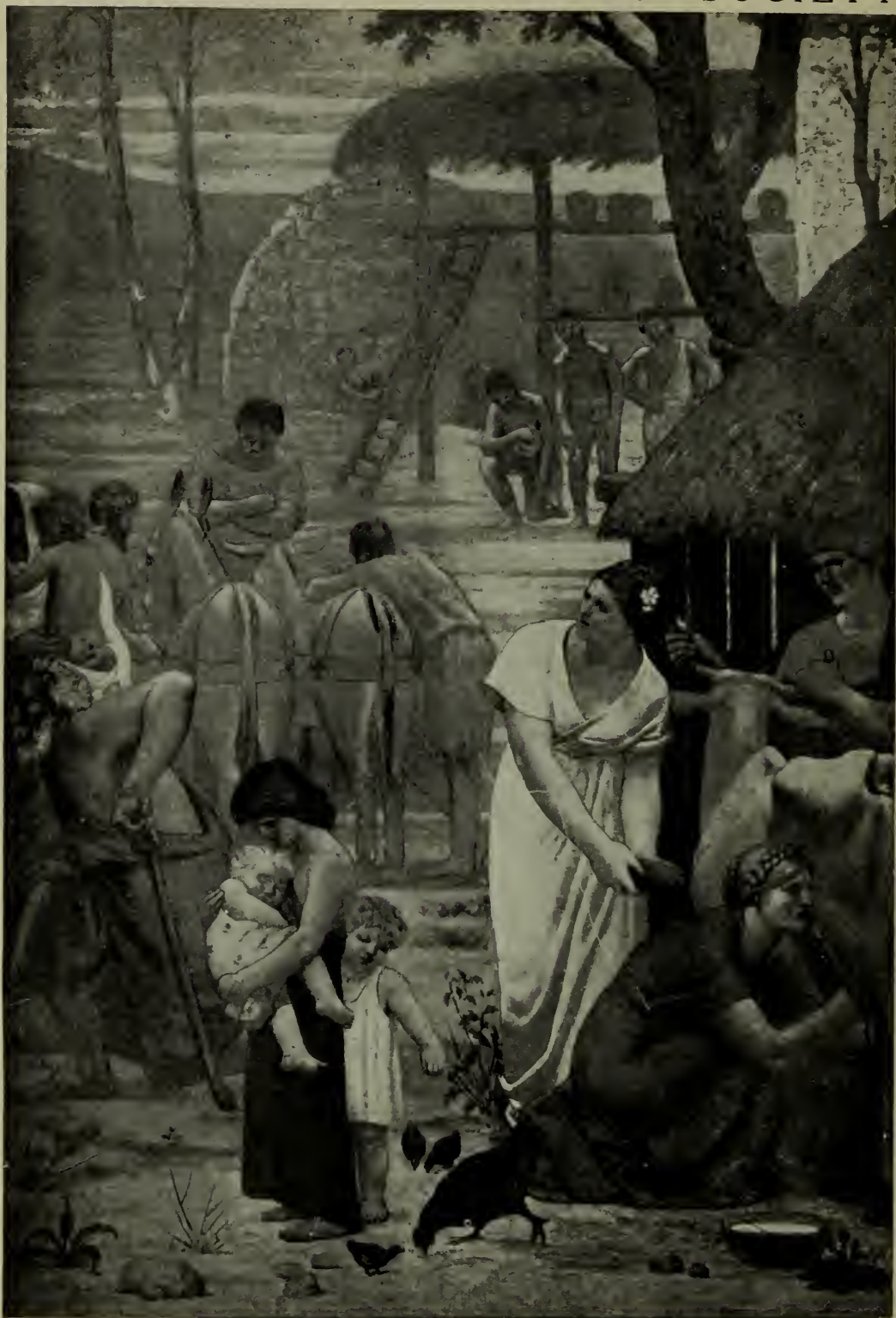
to be met with on all seas. They run to 14,000 tons burden, and can travel 11 knots. All over the world they carry petroleum and its many products. Kerosene, paraffin, benzine, gasoline, are among the most familiar. It is used to pour on stagnant water in malarial districts, to kill the mosquitoes which carry the disease. It is sprinkled on roads to lay the dust. It is thrown on stormy seas to calm the waves. In millions of homes it provides the only artificial light. It is banishing the horse from city streets and country roads. It has made it possible for men to fly in the air.

The Egyptians used petroleum ages before the Roman Empire. The Aztecs of Mexico and the Incas of Peru were familiar with it. The Indians as well as the Persians used it for its healing virtues before they ever dreamed that white men lived upon the earth. In China and Japan mineral oil deposits have been worked crudely from time immemorial. But it has been left to this age in which we live to discover the numberless uses and properties of this gift of nature, which has been made to add so largely to the comfort and convenience of the life of the world.



THE TERRIBLE SPECTACLE OF A TANK STEAMER ON FIRE, SOMETIMES VISIBLE 35 MILES AWAY

THE COMMON SPIRIT OF SOCIETY



© Braun et Cie., Paris

The chief triumph of man is Society, upon which the maintenance of civilization depends. In this picture Puvis de Chavannes has most aptly represented the fellowship and mutual aid upon which Society rests.

HOW MAN GOES ON FOREVER

The Wonderful Thing of Man's Making
which Lives on when its Maker dies

THE HUMAN REBELLION AGAINST NATURE

HERE has been a great deal of foolish talk about the future Superman. Nietzsche, a brilliant German writer, began it. Believing that, according to the theory of natural selection, the human race has gradually developed out of a low animal stock, Nietzsche assumed that mankind would at last disappear and make way for a still more advanced type of being. It was supposed that the superman would be evolved by savagely intensifying the natural struggle for existence. Nietzsche has been aptly termed the *enfant terrible* of Darwinism. His was, however, a loose and blind way of thinking. He left completely out of sight the most momentous event in the history of the world. Man has not waited for the slow production, by any process of natural selection, of a super-humanity. He has created it. It is a strange, and mighty thing: Society.

The fact is that man has now escaped from the ordinary pressure of natural conditions. He has grown to a tremendous height by transcending in a wonderful way the operation of certain laws of life. The last stage in the development of his physical powers is represented by those mechanical inventions which have enabled him to control external nature. The last stage in the development of his psychical powers is found in the moral and intellectual fabric of society by means of which he has been able to control human nature. In both instances man has overturned the ordinary process of growth and decay. He has fashioned something possessing the attribute of escaping destruction and continuing to work on after the death of the living thing which produced it.

It is very probable that since man rose from savagery to civilization, the general level of the intellectual capacity of the individual has not grown higher. The Dorian Greeks, the Romans, the Celts, and the Teutons acquired, in their primitive struggle with adverse natural conditions, the force of mind which they used in building up their civilizations. Yet, in spite of the fact that the mental powers of the individual have not increased for some thousands of years, humanity in that time has made remarkable progress in material comfort, in command over nature, in culture and morality. All these achievements are the direct results of an improved organization of society, by means of which the paralyzing limitation of physical heredity has been profoundly modified. This transcendence of an awful natural law is the first of man's greatest achievements over nature, and by far the most important. From it are derived all the other advantages now enjoyed by humanity, or brought within a prospect of enjoyment. Man's first grand revolt was his transcendence of a harsh, restricting law.

And how successful has been his rebellion! As his social progress is not wholly dependent on the forces that govern the lives of the brutes, he has been able quickly to create a glorious heritage of civilization by means of which he supplements to an extraordinary degree the feeble powers which he obtains by natural heredity. A man now makes two bequests when he passes away. He still bequeaths to his children some of his physical and mental characteristics, but his high achievements — his mechanical inventions, and

his moral, artistic, and intellectual conquests — he leaves to mankind. The law of progress is that progress lies in the production and selection of useful variations, and certainly in the evolution of society there still obtains something like this law. In social organizations, however, the fruitful variation is not the individual as such, but his surviving thoughts. Thus we may say that the growth of the social fabric is similar to the growth of consciousness rather than to the growth of the physical body itself.

The modern civilized society is a sort of quasi-personality embodied in the common mind of its individual members. The

to learn in its lifetime, the less rigidly defined it must be at birth in the matter of instincts and special powers. What we inherit is a capacity to learn, and not, like the animals, an ability to perform. It is the plasticity of our instincts which gives us so adaptable a nature; and this plasticity enables us to acquire by social heredity infinitely more than physical heredity could give us.

The child comes into the world like a piece of soft clay, and the community into which he is born does much to mold his mind and his character, his feelings and his habits. Man, in short, is partly a social product. His race is of small importance



IN THE VERY EARLY DAYS

forces of the social world, however, are as subject to law as the forces of the physical world. In it are currents of attraction and currents of diversion; some bring the individual under the sway of the group; others enable the single man to strike out into some independent and original line of action. Of course, the natural socializing power is the gregarious instinct of the human being. This instinct, however, is not very strong; even in the lowest races it has to be supplemented by a certain curious mental acquirement. Man differs from all animals in that his instincts are not rigidly defined, and the instinctive part of his nature becomes smaller as he grows up. The more a creature is destined

when compared with his social race-conditions; even the action of his physical environment is slight in comparison with that of his social environment. Plato held that man was born with ready-made ideas which could never be acquired by mere experience. Locke, on the other hand, contended that all the notions we possess have their origin in individual sensation. Philosophers are still disputing the matter; but, looking at it from another point of view, it is clear that Plato's wonderful world of ready-made ideas has some sort of existence. It is the world of society. It is not we who think, says A. H. Post, a great authority on jurisprudence, but humanity that thinks in us.

But by what means does the individual acquire his social heritage? Here we come to the problem of that curious mental acquirement which supplements in the human being the instinctive ability of the animals. Man possesses in an extraordinary degree the faculty of learning by means of imitation. In this respect no monkey can compare with him. He is a marvelous mimic, and continually and unconsciously he mimics the modes of feeling, the frames of mind, and the ideas of the group in which he lives. This is how the intellect and character of a child are developed and furnished. A child turns to others as a flower turns to the sun, and he learns by imitation. Though few men and women know it, they also are constantly being molded in a similar way. There is a certain mild form of hypnotism which is called suggestion; and this force of



SOCIETY AS THE PROTECTOR OF THE CHILD
From a panel representing Law in remote antiquity.

real socializing power. It acts in the world of society in a manner dimly analogous to the way in which gravitation acts in the world of matter.

A modern crowd in a state of excitement often exhibits this force of social suggestibility in a more striking manner than a savage community. For, though more finely civilized, it remains sensitive to the action of the strange force which subjugates the individual in the interests of the group. Carried away by the wild spirit of an angry mob in, for instance, a political campaign, men sometimes lose their individual power of judgment, and do things of which they feel ashamed when they recover self-control. Mob action is an extravagant form of social suggestibility. By its hypnotic influence the spirit of the crowd enforces in an extreme way that social coöperation which is the ordinary requirement of any sort of common life.

Social thinking is the healthy engine of progress both in the creative and the conservative processes of society, and behind it must be the emotional, constraining impulse of social suggestion. But when the emotion of sociality breaks all bounds historic cataclysms occur.

The chief social force in all primitive communities

Certain conditions must, of course, obtain before a special emotion of sociality prevails in an extraordinary manner. If a Chinaman were swept up in an American crowd which was wildly roused by some athletic contest, or by the receipt of presidential returns, he would not be moved by the spirit of the crowd; and a French missionary in Asia Minor would not feel the contagious frenzy which sweeps through a multitude of fanatic dervishes. Mob feeling acts only on men united by common habits of mind; it is an aberrant, violent form of the social force which has already made them resemble each other in qualities and culture.

In a purely democratic form of society, in which the social leveling agencies have produced a general similarity of desire and an easily moved suggestibility, the spirit of the crowd is a most dangerous factor in the State; it is largely responsible for the destruction of real liberty and the prevalence of various sorts of license. In this case a strong-handed tyrant, or a subjugator at the head of a foreign army, is necessary to restore discipline and order.

Happily, the defect of too docile a responsiveness to social suggestion does not always lead to mob action. Indeed, as a rule, it makes for a rigid conservatism.

The imitators who carry on the experiences and achievements of the race

On the one hand, it is responsible for freaks of fashion and epidemics of wild thought and blind feeling. On the other hand, it keeps alive foolish superstitions and outworn usages and conventions, and it produces inertness of intellect and stagnancy of emotion. Social suggestibility at its lowest is imitation reduced to mere repetition.

A man does something just because it is "the thing" to do it — that is, because other people are doing it.

Unintelligent social imitation of this kind is the chief force in all primitive communities. It is probable that every individual savage is capable, in favorable circumstances, of some degree of invention, but the social group to which he belongs compels him to live entirely by imitative routine. All social actions thus become by repetition rigid social habits, and the principle of growth and progress is entirely lacking. Human society in the purely imitative stage of culture is scarcely a higher form of organization than the animal societies which are maintained by mere gregarious instinct. One of the few good results of war is that conquest does sometimes break down the purely imitative organizations of some of the lowest races. When the victors owe their victory to some sort of social progress, they introduce among the vanquished new elements which will, perhaps, stimulate the latter's latent powers of invention.

Will a high civilization utterly abolish the human struggle for life?

On the whole, however, the social imitative spirit of mankind is an instrument of sane and steadying power. Some important societies have been preserved by the mere repetition of thought and custom, especially when there was much sound matter in the traditions established by the ancestors of the race. Sparta, so unprogressive when compared with Athens, is an example of this healthy conservatism; and China, which has outlasted all the progressive empires of the ancient Western world, is a still more remarkable example.

In a general view, the social spirit of imitation, if not more important, is more fundamental than the individual spirit of originality. It preserves and carries on all those great traditions, those vital conventions and instruments of civilization, in which are resumed the experiences and achievements of the whole human race. Burke has said that no man could trade on his private stock of reason. As a matter of fact, reason is a social thing; it is by

imitation that a child acquires the supreme faculty of speech, and the thoughts he develops by means of language. A solitary man could not live a full life even on the results of the best sort of conscious education.

In many social matters one learns in a glimpse, by imitative suggestion, more than could be acquired in many hours by explanation and study. The life of the individual is short and shallow, but the traditional wisdom of society is far-reaching and profound. Mankind is a wiser philosopher than any man, and, seeing that our intellectual and emotional habits are mainly formed by social suggestion, it is impossible for the most independent mind to free itself sufficiently to criticize its own foundations.

We are all social products rather than social units. No doubt during our generation society is largely embodied in us, yet we do not represent the whole of society.

Imperial spirits
Rule the present from the past,

as Shelley said; and in the social conscience the interests of the future are also guarded.

Some thinkers have endeavored to show that enlightened self-interest would make a man a good member of society. This, however, is a mischievous view. For it is possible to make rules of individual action which contain the highest wisdom and are

yet unsocial. These rules would be those dictated by discretion and convenience, expediency and the attainment of personal happiness. Such motives are indeed found in all defensive and aggressive organizations, and in most of the productive and distributive agencies of civilization. Intelligent, self-regarding action, with the aim

of success, is now widely employed in political and industrial life, and on its apparent utility in these fields there has recently been formed a gospel of national efficiency.

Little or no progress of society, however, can be effected by organizing all the machinery of a nation on purely scientific lines. For society is at root an organization for the development of social morality. By means of it, the harsher struggle for life has been mitigated with a view to its entire abolition. The only natural struggle which is valid in the high-

est sort of human civilization is the struggle against the agents of disease. Here, until less than a hundred years ago, man unconsciously competed against man in a fierce selective process in which the microbe acted as the selector. It wiped out weak stocks and individuals with feeble constitutions, and by a long, agonizing struggle it forced the race to keep strong and immune. Alcohol and narcotic drugs are also selective agents in a natural struggle between the members of society. Now, however,



DESPOTISM AND CIVILIZATION ONLY 20 YEARS APART

These two pictures show in a striking way the rapid spreading of ideas in society. The upper picture shows a law court in old Japan; the lower picture shows the Japanese parliament fully established less than 20 years later.



Copyrighted by Detroit Publishing Co.



"PANELS OF THE PEOPLE," SUGGESTING THE ADVANCE OF SOCIETY TO A HIGH STATE OF

the community is beginning to protect all its members even against these natural agents of selection. This is the supreme triumph of social morality.

As society does so much for the individual — gives him his language, his feelings, his thoughts, his craftsmanship and industry, his customs and institutions, his creed and his government — surely society has the right to restrain his purely selfish interests when these conflict with the interests of his companions and the interests of future generations. This restriction is effected by means of the social conscience. Now we come to a very interesting but somewhat difficult point in our examination of the relations between the individual and the community. We have seen that to a large extent the mind and character of a man is a social product; and so, too, is his sense of right and wrong. To put it briefly, a man cannot think of himself except in terms of other men. As a psychologist would say, the social situation is implicated in the thought of oneself. A man does not need to consider "What will people say of this selfish action of mine?" His con-

science tells him; it represents the social force in its highest and purest incarnation.

This seems intelligible at first glance, but in one of the last of his writings Huxley raised an apparently well-founded objection. His point was that if the moral sense were the outcome of social relationship, then a man ought to feel an obligation to perform the bad acts in which society indulges, as well as the good acts. Now, this really happens in certain circumstances. Very young children, for instance, sometimes feel impelled to imitate everything; a selfish action arouses their selfishness, and a generous action provokes their generosity. A somewhat similar thing is seen in savages of an inferior type, and it perpetuates the horrible vices and the sanguinary customs of very low races. The individual begins by imitating both the good and the bad elements in the social group. In civilized but relatively backward communities, too, we find dueling and private vengeance most rigorously enforced by the social code.

But, in order to create any kind of improvement whatever in social organization, a man must rise superior to the society



Copyrighted by Detroit Publishing Co.

CIVILIZATION IN WHICH THE BITTER STRUGGLE FOR LIFE WILL PROBABLY ENTIRELY DISAPPEAR

in which he lives. In other words, the socializing power of imitative suggestion must be supplemented by the individual faculty of invention. There are, however, so many constraining and leveling social forces that it seems as though the individuality of a man is thereby suppressed.

This, however, is not the case. The better organized a society is, the greater is the power of the individual. To put it in a paradoxical way, the more imitative a person is, the more original he will become. To a large extent both genius and talent are based on a capacity for real assimilation. The more living knowledge a man obtains, the greater powers of thought and creative imagination he develops. Genius is measured by its scope. Minds of the highest order, such as Shakespeare's and Newton's, have an extraordinary faculty of assimilation. In such minds are brought together for the first time elements of knowledge which formerly existed only in scattered traditions or separated sources of information. Their originality consists in making a novel combination out of pieces of old material.

This may seem a poor kind of originality, but it really is creativeness of a supreme kind. It is the sort of creativeness on which the progress of society entirely depends. This is explained by the profound difference between the world of matter and the world of mind. The world of matter is composed of a mass of energies varying in appearance but unchangeable in quantity; nothing can be added to it; there is no progress in it; only a process of evolution and dissolution. But in the world of mind there can be a continual creation of new elements. There is no justification for saying that a physical fact is new merely because it has just been discovered; but every new idea brings into the world of mind something which did not exist before. If it is a great social idea it may give a new direction to the course of human development and increase the powers of every individual.

For the powers of each individual are augmented by every improvement in socialization. The richness of his social heritage is extended; the amount of contemporary knowledge at his disposal is made greater;

and his personal influence is widened and deepened. His inventions may revolutionize the life of the community; his discoveries may add vastly to its resources; his literary work or scientific writings may set the aspirations of a nation and mark an era in the history of mankind. When we remember that the modern steam-engine was once only an idea in the mind of a Glasgow instrument maker, and when we recall that Watt only slightly improved on a first principle of mechanics already worked out in practice by innumerable men, we can see clearly how small the originality of an individual may be in quantity, and yet how vast it may be in quality. In the world of thought it is often the little new things that tell, especially when the slight novelties are closely related to older achievements, so that the development appears natural and involves little divergence.

Men progress by tiny steps rather than by bold jumps

Too great an originality of mind in the individual is sometimes fruitless. It is rightly said of men of the stamp of Roger Bacon that they were born before their time. The new thoughts of an inventive mind must be only a little above the average intelligence if they are to produce an immediate and a wide effect. It was by imitation that the inventor acquired his materials from society, and it is by imitation that society, in turn, acquires from him his new idea. The need for campaigns of education to effect the most evident of social reforms shows that the general mind of the community is usually on the side of the average conservative man. So the less distance there is between a new idea and the traditions from which it is worked out, the less resistance there will be to this idea becoming incorporated in the social fabric. When we talk of inventive minds, especially in connection with the progress of modern civilization, we do not refer exclusively to men of genius or superior talent. Every normal member of a highly civilized community possesses some initiating power. Few civilized men live a life of purely repetitive imitation;

by their work, by their example, by a thousand little unremembered acts, they play some part in casting the social heritage into a better or worse form, and in handing down this new form to the next generation. One of the chief results of the new science of society is to rehabilitate the power of the individual. Instead of regarding social institutions, ideas, and sentiments as the spontaneous product of the nameless multitude, modern science rightly considers them the achievements of individuals. The individual genius, however, is mainly a product of the social spirit, and its new ideas, in order to be effectual, must be consolidated, diffused, and preserved by imitation in the social mind. Then, from the contents of the social mind, the materials for new inventions are in turn obtained by the great minds of the next generation. Thus there is a constant give and take between a society and the individuals composing it, and out of this give and take, in favorable conditions, the forces of progress are evolved.

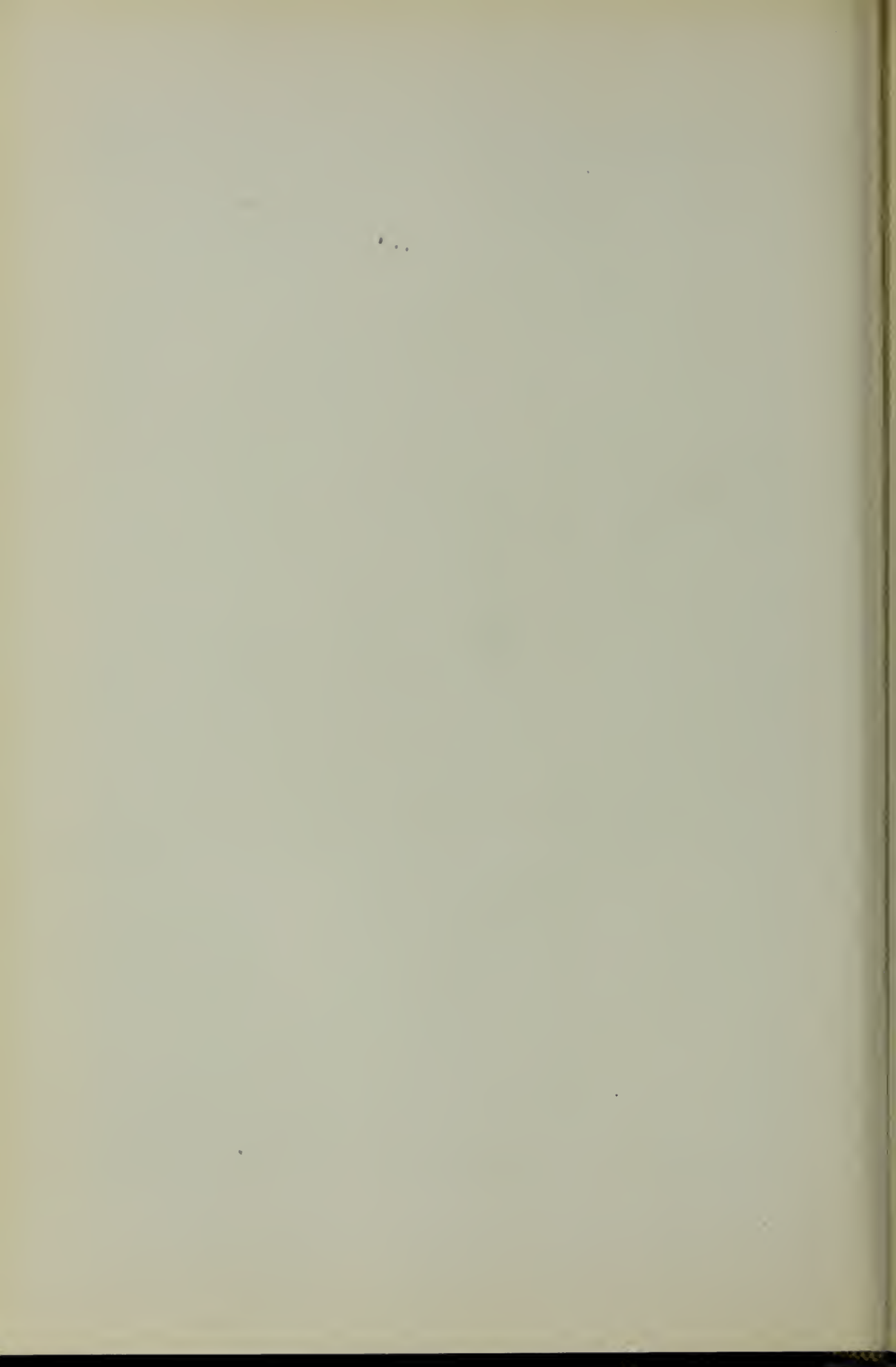
What most contributes to the development of a community

What is it that contributes most to the development of a community? Some men of science, we are afraid, might be tempted to reply that intellectual power, and the wonderful knowledge now being obtained by the exercise of that power, are the great factors in social progress. But the truth is probably that a higher morality, a finer and more sensitive conscience, are the main things necessary to the development of human society. In order to get men to coöperate in promoting the general welfare, we must first break down the barriers of selfishness. Selfishness has many shapes, some gross, some subtle, and it is probable that many men, in following their own personal ends, have indirectly done social good. But, as was said before, the most enlightened self-interest is not a true form of sociality. No self-interest, however enlightened, will by itself lead a man to act for the benefit of future generations. Yet, whatever any man holds, he holds purely as a trustee. It is a legacy slowly accumulated by tears and blood, by

THE TRANSFORMER OF SOCIETY



It is by no mere chance that Christendom has become the center of a civilization radiating over the earth, for Christendom is the historic example of socialization on a large scale, combining diversity of language and tradition with common creeds and institutions. We may think of Paul, therefore, as a great transformer of society, who, in saving Christianity from becoming narrow—by talking to his jailers or by writing letters from his prison-house—gave new strength to a spirit which has woven itself in the very structure of the modern world.



struggle and self-sacrifice, of innumerable generations of men and women who have gone before us. It is our duty to sacrifice a little of our comfort and devote a little of our labor to the task of improving this legacy of society, and doing for those still unborn what those now dead did for us.

The question of social progress is now largely a question of the development of social morality. Having mitigated the primitive struggle for existence and come to coöperate together, we must moralize natural law, by a deep-seated feeling of love for our fellow-man. As struggle is the older law of nature, so love is the spirit of society, and thus the new law of nature.

It is by no chance that Christendom, despite its disinclination to put in practice the Sermon on the Mount, has become the center of a civilization which is radiating over the earth, even in Japan and China, in Persia and in Turkey, and producing vast revolutions in these ancient states. Formod-

ern Christendom is the best example in history

of socialization on a large scale. It combines a useful diversity of languages and local traditions with the unifying factors of common creeds, similar institutions of learning and government, and a vast common fund of culture. As the recent congress of races shows, there is now beginning to obtain a larger sense of commonalty, and even in the last terrible war there was a deeper and more general appeal to the common conscience of Christendom for approval and support than was known in the Napoleonic wars.

No doubt the steamship, railway, telegraph, and wireless have brought nations

into closer contact, but mere contact is not society. For thousands of years neighboring nations have traded together without finding in commerce a consolidating and pacific power. What was wanting was an overspreading atmosphere of high thoughts and large feelings derived from some universal socializing power. This power has at last been created by the New Reformation begun in Christendom.

Irresistible forces of material interest and humanitarian feeling are drawing the nations together. The Great War itself, in spite of the hatreds it engendered, has given a great impetus to the movement. It has shown that no nation can live to it-

self, that, in the words of President Wilson, none can remain neutral against a disturbance of the peace of the world. The time-honored American policy avoiding all "foreign entanglements" is no longer tenable. Our country is feeling its way toward some plan of world organization which will

prevent war without involving us in old-

world rivalries and conflicts of interest in which we have no concern. The departure from our historic traditions naturally means a struggle, but some change is recognized as necessary. The League to Enforce Peace, organized at Independence Hall, Philadelphia, in 1915, was a forerunner of the League of Nations. This was too great a step, and had so many objectionable features that America has refused to enter it. But the Washington Conference to limit armaments, the Four Power Treaty to preserve peace in the Pacific, and President Harding's suggested Association of Nations, all show the inevitable drift of events.



THE PUBLIC BURNING OF OPIUM PIPES IN CHINA

New forces are quickening the heart and mind of all the peoples of the earth, lifting them up on the wave of common hope into a higher state of civilization; and no national example of this uplifting movement can compare, in dramatic intensity and far-reaching potentiality, with the national war against opium in China.

A GREAT INTERNATIONAL NATURALIST



LOUIS AGASSIZ

NATURALISTS AND BIOLOGISTS

LOUIS AGASSIZ — THE FIRST NATURALIST OF HIS TIME
 JOHN JAMES AUDUBON — AMERICAN NATURALIST AND ORNITHOLOGIST
 SPENCER FULLERTON BAIRD — ORGANIZER OF THE SCIENCE OF FISH CULTURE
 SIR JOSEPH BANKS — NATURE-TRAVELER
 HENRY W. BATES — AMAZON NATURALIST

LOUIS DANIEL BEAUPERTHUY — PIONEER IN FIGHTING TROPICAL DISEASE
 SIR CHARLES BELL — THE INVESTIGATOR OF THE NERVOUS SYSTEM
 CLAUDE BERNARD — THE CHEMIST-EXPLORER WITHIN THE BODY
 FRANÇOIS BICHAT — FOUNDER OF THE SCIENCE OF MINUTE ANATOMY

LOUIS AGASSIZ

The First Naturalist of His Time

JEAN LOUIS RODOLPHE AGASSIZ, one of the most popular men of science of the second and third quarters of the nineteenth century and a strong and consistent opponent of the Darwinian theory, was born at Motier, in the Canton of Fribourg, Switzerland, on May 28, 1807, the son of a clergyman. His education, begun at Lausanne, was continued at Zurich, Heidelberg, Erlangen and Munich. He was graduated in medicine and took a further degree in philosophy. His taste for zoölogy, developed by his early studies, brought him in Munich into relations with Martius and Spix, and his arrangement and description of the latter's collections of Brazilian fishes attracted the attention of Cuvier, whose pupil he became in Paris. When only twenty-four years old he was appointed professor of natural history at Neuchâtel and it was during the fourteen years he retained that chair that he completed his first great work on fossil fishes (*"Recherches sur les poissons fossiles,"* 5 volumes). From fishes he enlarged the range of his observations to invertebrate animals, which he studied in both living and fossil forms, and he quickly obtained a European reputation. In England in 1834 he made the acquaintance of Hugh Miller, and by his appreciation of the studies of the Scottish stone mason helped to popularize that unfortunate genius. His visits to the British Isles resulted in his "Fossil Fishes of the Old Red Sandstone." On

his return to Switzerland, Agassiz took up the study of glacial movement and his theories attracted universal attention.

In 1846 he was invited to deliver a course of lectures at the Lowell Institute in Boston, and these were so much appreciated that he was appointed professor of natural history in the Lawrence Scientific School of Harvard, and joined the circle of delightful men who in that day gave Cambridge distinction in the world of literature. One of his innumerable activities was the foundation there of the Museum of Comparative Zoölogy, one of the most extensive and scientifically useful in the world. To its development he devoted his enormous energy and enthusiasm, obtaining public and private subscriptions for its extension and maintenance and remaining always poor from his own liberality to it. Even the holidays which so rarely diversified his strenuous work were spent in scientific excursions, and carried him as far afield as Brazil (1865). His investigations in the Alps had convinced him of the need for the study of nature where the objects under observation were *in situ*, and he therefore established on the island of Penikese, in Buzzard's Bay, a practical school of marine zoölogy. This was the precursor of all the summer schools that have since done so much for the encouragement of scientific knowledge. Among a number of other important works published during these years was "Contributions to Natural History of the United States," in four magnificent volumes.

The work of Agassiz had the double character of original research and popular exposition, and as a lecturer he was in constant demand. In its enthusiastic prosecution he wore himself out. He died at Cambridge on December 14, 1873. His grave is marked by a glacial boulder from the valley of his native Aar. The impression made by the personality of this charming man of science is reflected with fine truth and delicacy in the poem,¹ read by Longfellow at the meeting commemorating his fiftieth birthday, May 28, 1857:

It was fifty years ago

In the pleasant month of May,
In the beautiful Pays de Vaud,
A child in its cradle lay.

And Nature, the old nurse, took
The child upon her knee,
Saying: "Here is a story-book
Thy Father has written for thee."

"Come, wander with me," she said,
"Into regions yet untrod;
And read what is still unread
In the manuscript of God."

And he wandered away and away
With Nature, the dear old nurse,
Who sang to him night and day
The rhymes of the universe.

And whenever the way seemed long,
Or his heart began to fail,
She would sing a more wonderful song
Or tell a more marvelous tale.

So she keeps him still a child,
And will not let him go,
Though at times his heart beats wild
For the beautiful Pays de Vaud.

Though at times he hears in his dreams
The Ranz des Vaches of old,
And the rush of mountain streams
From glaciers clear and cold;

And the mother at home says, "Hark!
For his voice I listen and yearn,
It is growing late and dark,
And my boy does not return!"

Though some of the views held by Agassiz have been overthrown, and his work was too wide and eager to be always exact, he holds an honorable place as a devotee of science and his influence on the group of men whom he gathered about him and trained at the museum was incalculable.

JOHN JAMES AUDUBON

American Naturalist and Ornithologist

JOHN JAMES AUDUBON best known of all American ornithologists, was the son of a Frenchman, while his mother was of Spanish extraction. Oddly enough, though his descendants have religiously preserved all memorials of him, the date of his birth is not precisely known — it is probably 1780. He inherited from his father a fine estate in Louisiana, where his earliest recollections "were associated with lying among the flowers of that fertile land sheltered by the orange trees, watching the movements of the mocking bird." Early in life he was removed to France, and as a schoolboy during the Reign of Terror received a thoroughly national education, being taught to play upon the violin, flute, flageolet and guitar, and to become proficient in dancing; while for drawing master he had the famous David.

He came to America, where his father had property, and about the time of attaining his majority launched out as a gay young Pennsylvanian squire. At Mill Grove, hunting, drawing and fishing occupied his every moment, until he made a happy marriage with a charming English girl, Lucy Bakewell, the daughter of a neighboring land owner: a match which made, reformed and beggared him. His father-in-law insisted that he should go into trade and like many another unlucky man of business, he never discovered his true vocation till he was ruined. His partners may have been honest; and they may be excused if they were disgusted and inclined to take advantage of him. They might tempt him to venture his all in risky speculation, but they could never keep him to the inside of the counting house. He was as keen to break away to the woods and fields as any falcon secured to the perch. "Were I to tell you," he writes in his note-book, "that once when traveling and driving several horses before me, laden with goods and dollars, I lost sight of the pack saddles and the cash they bore, to watch the motions of a warbler, I should only repeat occurrences which happened a hundred times and more in those days."

¹ Reprinted by permission of Houghton, Mifflin Co.

And the locations in which the speculators settled offered him rare opportunities and irresistible temptations. He was first at the township of Louisville on the Ohio; afterwards at Henderson, a hundred miles lower down the river. The woods, the wolves, and the Indians came up to the skirts of the settlement, the country was sparsely dotted over with squatters who lived chiefly by their guns. The inevitable followed: the Pennsylvanian plantation was sold, his debts were paid, and he was left without a dollar. "Was I inclined to cut my throat in foolish despair? No! I *had* talents and to them I instantly resorted." He stood then at the parting of the ways and immediately he struck into the path which led to fame and reasonable affluence. His mind overflowed with images of the feathered race and his fingers grasped the pencil to give form and shape to the surging thoughts in his great work, "Birds of America." The expense of production was great and lack of means compelled him to travel to Europe and wait patiently in the anteroom of princes who might subscribe for his book. The introductions that he carried with him, as well as his reputation and the object of his journey, insured his meeting with all the most cultured and most wealthy in the cities of his progress, so that from his memoirs we get interesting scraps of conversation with Sir Walter Scott, Wilson, Cuvier, St. Hilaire, Jardine and Gerard, as well as many other notables in the science, art and literature of Edinburgh, London and Paris in the late twenties.

By 1838 the 87 parts of his great book (containing 435 plates with 1065 figures) had all been published. No reading matter accompanied the plates, but this was prepared later and published in 5 successive volumes entitled "Ornithological Biography."

The years from 1830 to 1842 were spent in almost incessant travel in all accessible parts of the United States and Canada, in search of new material, or else in Europe attending to the publication or sale of his book. But in 1842 Audubon purchased an estate on the banks of the Hudson where he established a beautiful home for himself, his sons, and their families.

After 1847, the naturalist failed rapidly; he gradually lost the use of his mind, died in 1851, and was buried in Trinity Cemetery, New York, close to his home woods which now form a beautiful district called Audubon Park.

It has been said of Audubon that in everything he attempted to follow nature: before he began to draw a bird he would study its life-history, its birth and development, its food and its courtship. "If he shot a duck, the grasses and weeds among which it was found formed the



JOHN JAMES AUDUBON

From a painting by F. Cruickshank.

accessories of his drawing. If he brought an eagle down from his eyrie, the very deadened limb that last bore the impress of his talons was secured at any sacrifice, and the bird reappeared just as he first attracted the eye of the naturalist. And this care extended to the humblest of the feathered tribe; the apple-tree blossom, the thorn, the ripe fruit, the gigantic caterpillar, the variegated spider, and a thousand other hints of rural life crowd in profusion the drawings of his birds, until they appear as complete pictures, stories perfectly told."

SPENCER FULLERTON BAIRD
Organizer of the Science of Fish Culture

SPENCER FULLERTON BAIRD, the American zoölogist, was born in Reading, Pennsylvania, on the 3d of February, 1823, and, after several years attendance at the public schools, graduated from Dickinson College, in his home state. During his early college days, he attracted wide-spread attention for his studies and observations in nature. He had a powerful robust constitution, and was an assiduous collector with a strong



SPENCER F. BAIRD

intuition for the work, hence he accomplished much in his tremendous walks of from twenty to fifty miles a day across country. On an ornithological excursion through the mountains of Pennsylvania he walked 400 miles in 21 days, and the last day about 60 miles. At this period he not only made remarkable collections in a variety of fields, but he began a system of exchanges with naturalists all over the country, which later on formed the basis for the fine and far-reaching system of exchanges which became a policy of both the Smithsonian and the National Museums at Washington.

During these earlier years he formed valuable acquaintanceships with Audubon and Agassiz and other leaders of American zoölogy. After studying medicine for a time, Baird became professor of natural history in Dickinson College in 1845, assuming also the duties of the chair of chemistry and giving instruction in physiology and mathematics. This variety of duties in a small college tended to give him that breadth of scientific interest which characterized him through life, and made him perhaps the most representative general man of science in America.

For the long period between 1850 and 1878 Baird was assistant-secretary of the Smithsonian Institution, and on the death of Joseph Henry he became secretary. From 1871 till his death he was United States Commissioner of Fish and Fisheries.

The motto of James Smithson, the one which he gave to the Institution which bears his name, was "the increase and diffusion of useful knowledge among men," and Baird adopted this and followed it closely. His original researches were brilliant and far-reaching, but his greatest work and best energies were exerted along the lines that produce results of practical benefit to the human race. The appointment of Baird as United States Commissioner of Fish and Fisheries marked an epoch in the development of economic science in America.

Baird constructed the framework of the department to prosecute investigations into the question of the diminution of valuable food fishes, and for the adoption of preventive measures. Experts were sent all over the continent, hatching stations were established and available fish were carried from one part of the country to another. The striped bass which has been disappearing on the Atlantic coast was introduced into the Sacramento River and today it is caught in large quantities and is the highest priced fish on the Pacific coast. The famous rainbow trout of California was transplanted to eastern waters, and government vessels searched the sea for new fishing grounds contiguous to the coast that would prove valuable to American fishermen.

For thirty-three years Baird gave his strength to the upbuilding of the Smithsonian Institution: he exploited a number of expeditions, and by interesting every branch of the government — its consulates, surgeons, ministers, revenue service, marine corps, engineering departments — induced them to send in animals, plants, minerals, fossils, fruits, flowers, and implements from the localities in which they were stationed.

The world did not fail to recognize the signal ability of this great naturalist: from the king of Norway and Sweden he received in 1875 the decoration of Knight of the Royal Norwegian Order of St. Olaf, from the Society of Acclimatization of France its gold medal in 1879, and from the emperor of Germany the *erster Ehrenpriez* of the International Fischerei Ausstellung. Foreign societies vied with those of this country in doing him honor: and but for his extreme modesty many more distinctions would have been conferred upon him.

Early in 1887 Baird showed symptoms of failing and the physicians ordered complete rest; in the seaside laboratory at Woods Hole — the summer headquarters of the United States Fish Commission which had been reared by his hands and planned by him — he died in that same year. Of his many publications the most important volumes were "Birds" in the series of reports of the surveys for a railway route from the Mississippi to the Pacific Ocean (1858); "Mammals of North America, Descriptions based on Collections in the Smithsonian Institution" (1859), and the monumental "History of North American Birds" (1875-1884).

SIR JOSEPH BANKS

A Nature-Traveler Round the World

SIR JOSEPH BANKS, famous English botanist, was born in London on February 13, 1743. He was educated at Heron, Eton and Oxford, and it was owing to his interest and exertions that lectures in natural history were introduced into the curriculum of that university. He was a man of considerable inherited wealth, which he devoted to the great interest of

his life, and in 1766 after being elected fellow of the Royal Society, he began his travels as a naturalist by visiting Newfoundland and Labrador, from whence he brought back the first scientific botanical collections from that region. Two years later he accompanied Captain Cook on his voyage round the world in the *Endeavour*, a ship provided by himself. With him on this voyage was his friend the botanist Solander, a pupil of the great Linnæus, and from the first it could be seen that Banks meant his collections to be systematic and exhaustive, after a



SIR JOSEPH BANKS

fashion that would have pleased the father of systematic nomenclature himself. Botany Bay, Endeavour River and Banksland were named at this time by Captain Cook.

Banks, in subsequent explorations, was the discoverer of the great geysers of Iceland. At the early age of thirty-five he became president of the Royal Society, a post which he retained until his death, more than forty years later. He accepted a baronetcy in 1781. He died at Isleworth, on June 19, 1820, bequeathing his books and great botanical collections to the British Museum, where they have immensely aided the work of subsequent naturalists. Banks published little himself but he aroused the interest of others in natural science.

HENRY WALTER BATES
The Naturalist on the River Amazon

HENRY WALTER BATES, an English naturalist and traveler, was born at Leicester on December 8, 1825. Before he was twenty, he met Alfred Russel Wallace, who was only a couple of years older, and in 1848 the two set sail for South America, paying their expenses by the sale of duplicate specimens. There they worked together for two years, and for



HENRY BATES AMONG THE TOUCANS

nine years more Bates continued his travels and observations along the upper Amazon, succeeding in collecting eight thousand species of insects formerly undescribed.

On his return to England he was appointed, in 1864, assistant secretary to the Royal Geographical Society, and in that post he did useful work of an executive kind for science. In the preceding year Bates had published his "Naturalist on the River Amazon," which is a classic.

The pioneer work of Bates as a describer and collector of new living forms will always stand to his credit, though such work, like much which was more necessary in the

past than today, is purely of a mechanical and routine order. Interpretation, the ultimate aim of science, is the essential matter; and on this plane the name of Bates will always be associated with his interpretation, based on his observations on the Amazon, of the resemblances which are sometimes found between individuals of species far removed in the kingdom of life — even between leaves and insects, and also between living organisms and the color or texture of their usual environment. The theory of Bates was a strictly Darwinian one, the argument being that the peculiar characters of the species which mimicked another, or its surroundings, were favored and produced by "natural selection." It is now, however, necessary to reconsider all these questions in the light of our accumulating knowledge.

Bates made a great collection of certain species of insects during his latter years. A large part of it is in the British Museum. He was elected a fellow of the Royal Society in 1881; he died on February 16, 1892.

LOUIS DANIEL BEAUPERTHUY
Pioneer in Fighting Tropical Disease

LOUIS DANIEL BEAUPERTHUY, a heroic pioneer in the struggle of the white races against the deadly diseases of the tropics, was born in the island of Guadeloupe, in the West Indies, in 1803. He studied medicine in Paris, and became a physician with a strong biological turn of mind, and a skilful user of the microscope. In studying a disease, he would follow it up, no matter in what country it broke out. It was thus with that scourge of the American tropics — yellow fever. Whenever an epidemic of it occurred in the islands of the West Indies, he set off to make researches on the spot. In middle age, we find him at Cumana, in Venezuela, where a particularly virulent outbreak was ravaging the coast. He had then been making microscopic studies of the blood and secretions in various types of fevers for fourteen years, and the authorities appointed him a health officer. By 1856 he was able to draw the main outlines of a discovery that has had an extraordinary effect on the destinies of mankind.

"Marshes do not cause in man the slightest indisposition in equatorial and inter-tropical regions, notorious for their unhealthiness. Nor is it the putrescence of water that produces the unhealthiness. *It is the presence of mosquitoes.* Remittent, intermittent, and pernicious fevers, just like yellow fever, have as their cause an animal or vegeto-animal virus, the introduction of which into the human body is brought about by inoculation. The mosquito plunges its proboscis into the skin and introduces a poison that softens and breaks the red blood corpuscles. Intermittent fevers disappear or lose much of their severity in upland regions which have few of these insects."

Never in the history of medicine has so carefully thought out a prognostication received more remarkable scientific confirmation. Having practically solved the problem of the chief diseases of the tropics, Beauperthuy took up the study of leprosy. He died at this work in British Guiana, September 3, 1871. The value of his work was not recognized until, later, men of science found that certain mosquitoes and flies were the carriers of microscopic agents of diseases.

SIR CHARLES BELL

The Investigator of the Nervous System

SIR CHARLES BELL, a Scottish surgeon, eminent for his discoveries in connection with our nervous system, was born in Edinburgh in November, 1774. His father was a clergyman, and his mother, the daughter of a clergyman, was a woman of rare qualities. She had six children, of whom Charles was her youngest. From the Royal High School young Bell proceeded to the university of his native city, and thence to the dissecting-room and surgery of his elder brother, John, who was already well known. Charles, however, insisted that he had never received any real education except from his mother. She drew well, and the boy was naturally apt in the important business, as it then was, of drawing the facts which dissection revealed. These were the days before photography, and frozen sections, and the issue of anatomi-

cal plates prepared for use with the stereoscope, in order to get impressions of structure in natural relief. In an hour, now, the student may see, and display to others, more than would have cost Bell weeks of labor. For several years he devoted himself to this kind of work, until, to the lasting discredit of those in authority in Edinburgh, the jealousy of his seniors excluded him from any opportunity of continuing his work there; and when he was thirty years old he migrated to London, where his knowledge, enthusiasm and skill soon won for him great success as a teacher of anatomy and as a surgeon.

"Surface markings" and operation fees, however, were not enough to satisfy the mind of so original a student as Bell. For him the body and all its details, superficial and deep, had meaning, and it was to the elucidation of design, in the great sense, that his work was really devoted. Even before he came to London he had been led to study the nervous and muscular apparatus of the face and associated parts, not merely as anatomical facts, but as means for the expression of *psychical* facts. Hence his famous book, the "Anatomy and Philosophy of Expression," wherein he showed how the seventh or facial pair of cranial nerves, in man as in many of the lower animals, controls a numerous and complete group of tiny muscles, which were called by him the "muscles of expression," and which play a quite extraordinary part in the mutual relations of mankind. Paralysis of this nerve is now known as "Bell's paralysis."

Here is Darwin's verdict on his great predecessor in the study of expression: "He may with justice be said not only to have laid the foundations of the subject as a branch of science, but to have built up a noble structure." Darwin, too, quotes the opinion of a French student: "The book of Charles Bell ought to be studied by whoever ventures to discuss the visage of man, by philosophers as well as artists, for, under a lighter appearance and under the guise of æsthetics, this is one of the most beautiful monuments of the science which deals with the relations between the physical and the psychical."

These opinions are the more significant because of the fundamental opposition between Bell and his famous successor. Bell believed and taught, and sought by his researches to demonstrate, that man was specially created as he now is; indeed, the theory of special creation never had a doughtier champion than this close and searching student of the highest existing form of living organism. Darwin, however, was no common controversialist; there have been many cleverer men, but never one who was more generous.

Measured by influence upon the progress of exact knowledge, all the earlier and later work of Bell must be held secondary, compared with his great inquiry into the functions of the individual nerves which proceed to the body from the brain and spinal cord. In some cases the individual functions of these nerves were already known, as in the case of the seventh cranial or facial pair, studied by Bell himself. His great discovery dates from the year 1807, in which he published his essential results, finding order in chaos, and making possible thereby all further advance in our knowledge of functions and coördination of the nervous system.

Bell showed that there are nerves entirely sensory in function, nerves entirely motor, and mixed nerves which contain both kinds of fibers. This was in itself an enormous advance upon the view that any fiber of any nerve might act in any capacity; and it led to the recognition of motor and sensory nerve-cells, from which alone proceed motor and sensory nerve-fibers respectively. From this moment a real anatomy and physiology of the nervous system became possible. Finally, and most celebrated of all, came the discovery of the nature of the two roots of a spinal nerve. From the spinal cord, in man and the higher animals, there proceed numerous pairs of nerves, each of which nerves is formed by the union of two roots, one springing from near the front of the cord and another from a point farther back.

By dividing the roots of such nerves in living animals, Bell found that the anterior roots are always motor, and the posterior

roots always sensory, the nerves formed by their union being thus mixed nerves. This discovery was of crucial importance, not merely for anatomy, but in the practice of medicine and surgery, since from it has sprung that knowledge of the nervous system which enables us to recognize the meaning of a patient's symptoms of paralysis or loss of sensation, and to treat the thus found cause upon which his symptoms depend.

Though this part of Bell's work will always rank first for its practical significance, yet more was to follow, perhaps no less interesting from an even higher standpoint. As a devoted student of the mechanism of the body, Bell was entirely convinced that, in a thousand and one details, it showed evidence of creative design. In no other way could he account for the instances of coördination, of harmony, and of what we should now call "adaptation," which he encountered. Hence, in 1833, when he was one of the eight selected to write the *Bridgewater Treatises*, his contribution was a chapter on "The Hand," in which he dealt with "its mechanism and vital endowments as evincing design." Bell's published works on surgery and the nervous system were very numerous and of the highest value.

When the London University (now University College) was founded in 1826, Bell was put at the head of the department of medicine. In 1836 Edinburgh University paid him the tardy honor of recalling him as professor of surgery, and he held that chair during the last six years of his life. He had been knighted by William IV in 1831. Bell died, near Worcester, on April 28, 1842, and his body was buried in Hallows churchyard, under a monument bearing the following epitaph, written by his famous fellow-countryman Jeffrey: "Sacred to the memory of Sir Charles Bell, who, after unfolding, with unrivaled sagacity, patience, and success, the wonderful structure of our mortal bodies, esteemed lightly of his latest discoveries, except only as they tended to impress himself and others with a deeper sense of the infinite wisdom and ineffable goodness of the Almighty Creator."



SIR CHARLES BELL

CLAUDE BERNARD

The Chemist-Explorer within the Body

CLAUDE BERNARD, distinguished French physiologist, was born at Saint-Julien near Villefranche, on July 12, 1813. After a period, during which it seemed uncertain whether he was to become a playwright or a man of science, he went to Paris, and there became a pupil of the great Magendie, a notable figure among those who have applied experimental methods to the observation of living tissues. He was graduated in 1843 a doctor in medicine and in 1853 in science, and was appointed the next year to the chair of physiology in connection with the Faculty of Sciences. In 1855 he succeeded Magendie at the Collège de France

But his teaching was merely the economic necessity of so many original students before his time and since. However, Bernard found time for much research and also for the writing and delivery of a large number of lectures upon his results and their significance. He will always rank as the great master of chemical physiology in its broader outlines; and no student of digestion, excretion, the disorders of chemistry within the body, or the means of dealing with them, can count as other than a follower of Bernard.

His principal work was done and published in that extraordinary decade, the first of the second half of the nineteenth century, which saw the principal and essential work of so many great men.

By means of carefully devised and conducted experiments upon living animals, Bernard was enabled to reveal certain functions of such glands as the liver and the pancreas, which are possessed also by man; and, in fact, his results apply to organs of this type throughout the whole range of animal forms in which they occur. They opened the way not merely to a profounder understanding of the methods of the animal body, the subtlety and resource of its constitution and working, but also to the comprehension of human diseases, such as diabetes, which depend upon chemical errors, and which, until Bernard's time, could not possibly be understood, or even adequately defined. Thus to him we clearly owe the very great contrast between modern methods of treating and alleviating diabetes and allied diseases of nutrition, and those of the past.

The French Academy of Sciences awarded Bernard a prize for his first great discovery — that of the functions of the pancreas. This large and important gland, common to man and the higher animals far down the scale, had long been a mystery to physiologists. Bernard contrived to collect some of the pancreatic juice, so that it could be studied — no easy task in his time, and one which had been attempted without any effective success nearly two centuries earlier. Of his work on this gland, his biographer, the physiologist Sir Michael Foster, says: "Bernard at one stroke made clear its threefold action. He showed that it on the one hand emulsified, and on the other hand split up into fatty acids and glycerine, the neutral fats; he clearly proved that it had a powerful action on starch, converting it into sugar; and lastly, he laid bare its remarkable action on proteid matters."

Bernard thus went a long way, but he stopped short of the whole truth, for it was left to his successors to discover, not long after his death, that the pancreas also has another kind of juice, never yet seen or isolated, which is called its "internal secretion," and which passes into the blood, with profound effects upon the chemistry of sugar taken in the food.

It was in 1853 that Bernard published, in Paris, his "New Function of the Liver." For ages it had been known that the liver produces bile or "gall," which passes into a kind of temporary receptacle called the "gall bladder." The older physiologists had supposed that the liver was closely connected with certain states of mind and feeling, as, for instance, courage and amorous feeling. The terms "chicken-livered," "lily-livered," and many similar allusions in Shakespeare and elsewhere will occur to the reader. Bernard set to work to find out the facts.

By feeding two dogs, one on a diet which contained sugar, and the other on a diet which contained none, and then killing them, he found to his great surprise that, even in the latter dog, sugar occurred in the blood leaving the liver, though none was present in the blood entering it. He further found that the liver stores up sugar which reaches it from the bowel (when the diet makes that possible), and serves it out to the blood as the body requires it. The dog that had not been fed on sugar for eight days was, nevertheless, getting a supply of sugar in the blood that nourished it, derived from the store in the liver.

Bernard found that the liver modifies the sugar which reaches it, turning it into a substance called "glycogen," which simply means the "sugar-maker." Enough is allowed to pass on for the bodily needs — sugar being a chief source of energy in the animal body. But when and if the amount of sugar in the blood, as it leaves the liver to go to the body at large, is insufficient, the liver transforms part of its store of glycogen back into sugar, and sends it forward for use.

This was Claude Bernard's epoch-making discovery of what is called the "glycogenic function" of the liver. He showed what no one had suspected, that this organ, which produces an obvious secretion and discharges it by an appropriate canal, also produces an "internal secretion" of a vastly subtler kind, and in relatively infinitesimal quantities, which is capable of profoundly affecting the chemistry of nutrition — and without which, in point of fact, we could not live.

Nor is that discovery by any means all. Bernard had given us a clue to a new world in the all but infinite cosmos of the living body. Internal secretions were soon sought elsewhere, and found; and some of them, like that of the thyroid gland, are now among the most valuable and almost magical remedies known to medical science.

Last, we must rank Bernard's great discovery that the size of the smaller arteries, or "arterioles," is regulated by the action of two sets of nerves, one of which causes the arteries to contract, while the other causes them to dilate. The parts of the body — brain, muscle, skin, gland, whatever it be — supplied with blood from the arteries in question are thus starved or flushed as the case may be. Only the professed student of physiology can realize at all adequately where we should be today if we did not know of the existence of the vasomotor system.

Claude Bernard died in Paris on February 10, 1878, and was the first scientist to receive the honor of a public funeral. He was an officer (1862), then a commander (1867), in the Legion of Honor, a member of the Academy (1869), of whose grand prize in experimental physiology he had been the winner in 1861, and founder and president of the French biological society.

MARIE FRANÇOIS XAVIER BICHAT

Founder of the Science of Minute Anatomy

FRANÇOIS BICHAT, celebrated French anatomist and physiologist, was born at Thoirette (Jura), in 1771, the son of a physician, under whose direction the boy soon reached the clinique of Petit, the famous surgeon of Lyons. In 1793 he went to Paris, where, under Desault, who recognized his genius, after a few years he became a successful lecturer on anatomy, experimental physiology and surgery. He was already in the grip of consumption, but the disease could not prevent him from thinking and writing.

Bichat is known to all students of medicine as, in the first place, the founder of the science of minute anatomy — now-days called "histology," or the anatomy

of the tissues. He had no microscope in those days that could be trusted, but he founded histology none the less. Directly from his study of the structure of membranes and tissues, in health and in disease, Bichat concluded that vital processes are essentially opposed and antagonistic to those of the not-living world. Hence his celebrated definition of life as "the sum of the functions which resist death." To him we owe the name of "Vitalism," which expresses the essence of his teaching.

"There are," says Bichat, "in nature two classes of things, two classes of properties, two classes of sciences. Things are



MARIE FRANÇOIS BICHAT

organic or inorganic, their properties are vital or non-vital, the sciences are physiological or physical." Had Bichat lived another forty years, he would doubtless have modified and greatly extended his views, especially because he would have become acquainted with the discoveries of Sir Charles Bell and with the results which experimental physiology was soon able to obtain. After Bichat's time, but not long after, the cell-structure of living beings was discovered. Then, again, the chemists and physicists — Bichat was neither — such as Liebig and Helmholtz, began to suggest that physical energies are transformed in the living body, and that in no circumstances can any living

organism be found to disobey the physical law of the conservation of energy. Bichat's term "vital force," or "vital principle," required restatement in the light of these discoveries.

His principal works, containing the ideas which will always preserve his name, are his treatise on "Life and Death," published in 1800, and his "General Anatomy," published in the following year, when he was only thirty. His "Descriptive Anatomy," of which he published only two volumes, was completed by his

assistants after his death, which was hastened by ceaseless labors in the dissecting room, from which nothing else could stop him. He died on July 22, 1802, at the age of thirty-one, and his funeral was attended by more than six hundred of his adoring pupils, and by many representatives of the profession which he adorned. Napoleon, a consummate judge of genius, had his bust placed in the Hôtel Dieu, the great hospital of Paris, and the visitor may see a statue of him in the quadrangle of the present school of medicine.

BUNGALOWS MAKE PLEASING HOMES WHERE THERE IS AMPLE LAND



A low, picturesque example of Santa Barbara bungalow.



Photo Lee N. Passmore

A cobblestone porch and fence, features of this San Diego home.



Photo Lee N. Passmore

San Diego bungalow with small flower garden.



Seattle bungalow with shingle exterior.



Bungalow at Tucson, Arizona. The box cornice is a prominent feature.

THE BUILDING OF THE HOME

"Houses Are Built to Live in
and not to Look on." — Bacon

THE PLANNING AND DECORATION OF THE HOUSE

THE building of a home is an important undertaking, as it involves a considerable investment, which should increase and not decrease in value. In order that it shall be satisfactory in every detail to the owner, it is necessary to study carefully all the problems involved. The first one is that of finding a suitable location. Many factors must be considered, such as accessibility to the owner's place of business, nearness to school, purity of water supply, drainage possibilities, sewage disposal, water, gas and electric facilities, suitability of soil for building purposes, kind of neighbors, and whether or not property in the neighborhood is restricted.

Deciding on type and material

When the site has been selected it is necessary to determine the proportions of the building to be constructed. The house should be placed to get as much light and sunshine as possible in the rooms most used. A flat location is more suitable for a formal type of Colonial or Renaissance house. Irregular, sloping land with shrubbery and many trees offers opportunity for very informal, rambling houses of the English cottage type. Curving walks, winding roads, and irregular gables showing through the trees are very picturesque but need a rather spacious location. Again, a house must not only be suited to the land on which it stands, but should blend harmoniously with the houses in the near neighborhood. A very plain, severe type of Colonial house is out of place on a street where there are many rambling cottages with spacious lawns.

After the type of house has been decided upon, the kind of material used in construction should be studied. It is always cheaper to buy building material which is near at hand because transportation considerably increases cost. However, certain types of houses suggest at once a standard material. For example, a true Colonial house suggests wood with very wide clapboards; an English half-timber house suggests brick or stucco and timber. Frame construction is usually the cheapest, but the life of a frame house is many years shorter than that of a brick veneer, stucco, brick on tile, or solid brick, and, furthermore, is expensive to keep in repair. The walls need paint every two years, and where there is a great deal of dampness the wood decays quickly and needs to be replaced. Solid brick construction is usually the most expensive but its life is longest.

Getting the utmost in plan and design

After one has found a location, studied a possible type and material, one should secure the services of an architect. It is not absolutely necessary, but it is wiser, in order to get the utmost in plan and design. The prospective owner should be unwilling to risk the expenditure of so large a sum of money as is required in the building of a house without feeling sure that it is being wisely used and that he will get the largest possible return. Houses built by an ordinary builder and contractor, without the aid of a trained architect, are lacking in design and beauty, well built though they may be. And there is nothing incompatible between beauty and comfort.

DEALING WITH THE PROBLEMS OF HOME BUILDING AND MAINTENANCE

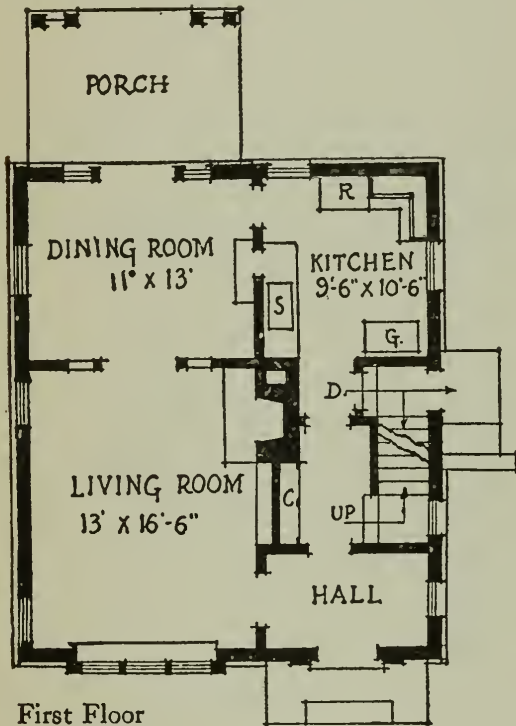
How to best plan the floor space

In planning a house the size of the family generally determines the number of rooms. There must be enough bedrooms although the number of rooms shared in common on the first floor is about the same for large and small families alike. Floor plans depend upon the shape of the lot and the location of the house upon it. A very narrow inside lot has not so much light on the sides as a

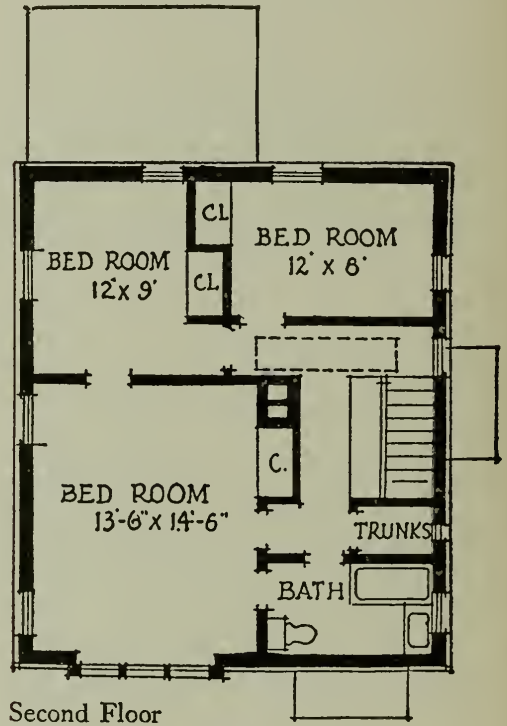
ant outlook. Very often with a sixty or seventy foot lot the house is placed broadside to the street, thus making it appear larger and giving more space at the front and rear where light is unobstructed. In this case the best arrangement is a hall in the center with rooms on either side (figure 2).

The various rooms and their relation

The Living Room: The ideal living room is very large and should have,



First Floor



Second Floor

Designed by Claude Bragdon, Rochester, N. Y. From The American Face Brick Association's "The Home of Beauty"

FIG. 1. FLOOR PLAN OF A HOUSE ON A NARROW LOT

corner one, and this means a narrower house with more windows at the front and rear in order to have unobstructed light (figure 1). The living room in such a house, if on the ground floor, should extend across the front, leaving one corner for the entrance hall; or it may be advisable to put the living room on the second floor to get the maximum amount of light. If the wall of the neighbor's house is very near, the windows might be set high in order to prevent an unattractive view. A very much wider lot is preferable in order to get better light and a more pleas-

ant outlook. Very often with a sixty or seventy foot lot the house is placed broadside to the street, thus making it appear larger and giving more space at the front and rear where light is unobstructed. In this case the best arrangement is a hall in the center with rooms on either side (figure 2).

if possible, a southern exposure. There are several ways of making them appear larger. For example, bay windows may be built and if the view is not desirable, the windows may be set high with shelves underneath for books. Another method is to have the living room open into the hall and the dining room, producing the effect of an extended living room. Sliding doors used always to be put in, but since designers have found that these are rarely used, they are now often left out and the openings made larger. Glass doors may be hung between the

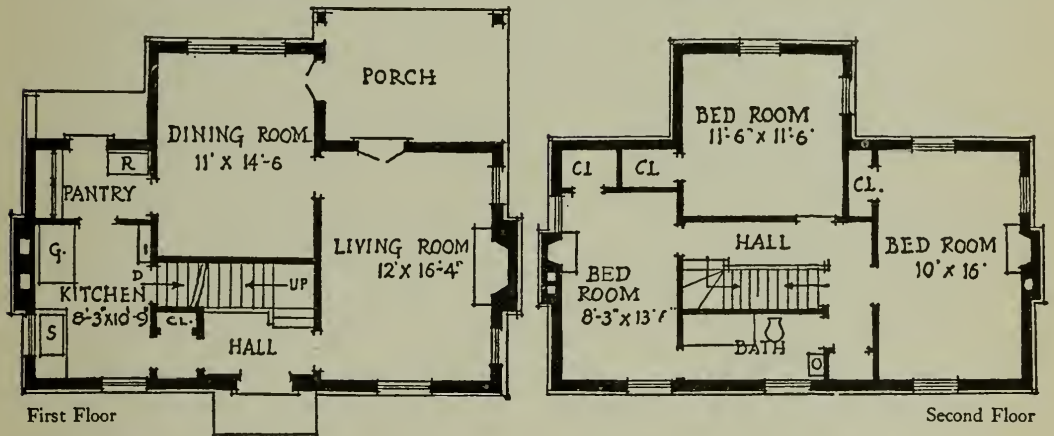
living and dining rooms so that the rooms may be shut off; even when closed such doors have the effect of making the living room appear larger.

The Dining Room is not so large as formerly was considered necessary. It is planned with reference to the size of the family and convenience in serving meals. If possible, it is wise to have the dining room placed so as to get the sun at breakfast time, that is, with an eastern or southern exposure.

If a round or square table is to be used, the room should be a little longer on the side where the sideboard is to stand. If there is a bay in the dining room, its windows may be high enough to place the

living room. But the stairs should be convenient to the front entrance, and not too far from the kitchen, especially in small houses where it is rarely possible to have a rear staircase. It may be possible to have a combination staircase, one in which a short flight from the kitchen joins the main stairs part way up. In a house with a central hall, the hall should be at least eight feet wide. Wide doorways or glass doors leading into the living room make the hall appear larger.

The Reception Room should be placed near the front door. It is not so much used as the living room and need not be on the most desirable side of the house. It should be located where callers can enter



Designed by Olaf W. Shelgren, Buffalo, N. Y. From The American Face Brick Association's "The Home of Beauty"

FIG. 2. FLOOR PLAN OF A HOUSE PLACED BROADSIDE TO THE STREET

sideboard underneath. To get the minimum size for the dining room, measure the table and chairs placed as they would be at the table, and add two feet on each side to allow space for serving. A room twelve feet square is the smallest size possible for a round table six feet in diameter accommodating six people. It is convenient to have two doors between the kitchen and dining room, for instance, on each side of a serving-room or pantry, to keep out the noise as well as the odors from cooking.

Halls formerly were made very large, even though the other rooms had to be small. Now the hall has been reduced in size and, indeed, is sometimes omitted, the stairs running up directly from the

without disturbing persons in the living room. Sometimes the hall is planned to serve as a reception room. A fireplace adds to its attractiveness.

The Library: The outlook is not so important a factor in planning its location but it should be a quiet room shut off from the rest of the house, and well ventilated, as it is often used as a smoking room. In the small house it may be necessary to use part of the living room for the library.

The Kitchen is the room to which the least thought in planning the house is often given. The housekeeper spends a great deal of time in this her workshop, and consequently careful planning is needed to help make it a pleasant room with every possible convenience. It is

a rather common fault to find the kitchen placed at the greatest distance possible from the front door, to which it should be convenient, in order to save the busy housewife's steps in answering the bell. Doors between the front hall and kitchen will prevent any noise or odors from greeting persons entering the home. The kitchen will be discussed in detail in the next chapter, so there is no need for further reference to it here.

Bedrooms above everything else need to have plenty of air. It is best to allow 1000 cubic feet for each person in a room. Thus a room $10 \times 10 \times 10$ feet, or $10 \times 12 \times 8\frac{1}{2}$ feet, will be sufficient for one person. The owner's room is usually the largest and best situated bedroom in the house. The furniture should be drawn out to scale on the floor plan, because so often in bedrooms there is no proper space left for beds, dressers, chairs, etc., after all the windows, doors and clothes-closets have been put in. The last should be more than just small enclosed hanging spaces, because drawers, places for hats, shoes, etc., should be included.

The Bathroom also needs careful planning and, with its fittings, should be drawn to scale. A large one gives more space to keep clean than a small one, which, furthermore, is more convenient if properly arranged. The best material to use for the floor is unglazed tile, but linoleum is very satisfactory. A small section directly over the pipes should be removable, as a convenience when repairs are necessary. Glazed white tile is best for the lower part of the walls, and above the tile the plaster should be covered with three or four coats of enamel paint.

The Basement should contain a well-equipped laundry, dust-proof coal bins, furnace room, a cool vegetable and fruit cellar, and if there is no attic, there should be room in the cellar to store trunks, boxes of material, etc. If they are placed on open racks, free from the floor, the contents will not become musty.

Verandas and Porches are very important and need to be placed with care. It is better not to have the veranda at the front of the house where there is no

privacy, and where it would cut off the light from the living room, but at the side or rear of the house. French doors are very pleasing opening from the living room or hall on to the veranda, which may be screened in summer and glazed in winter. The sleeping porch is becoming more and more a necessity, and is often put on top of the veranda. In this case it is better to extend the main roof of the house right over the sleeping porch, which otherwise will look detached.

The decoration and furnishing of the house to make it a real home

The art of decorating and furnishing a house to make it comfortable, attractive and artistic is little understood. To many it may seem to mean the expenditure of a large sum of money, the collection of a number of *objets d'art*, or the crowding of the rooms with a lot of elaborately decorated pieces of furniture. Nothing is further from the truth. What is needed is not so much money, as time and thought, taste and good judgment; and these can be developed by study and reading, and by acquainting oneself with the fundamental principles underlying the problem.

Quiet, harmonious colors and an orderly arrangement of simple and suitable furniture give an air of peace and contentment to a room. Love of beauty, ideas of order and neatness and standards of good taste are developed by artistic surroundings, especially in the minds of children; and the sense of beauty, which is more or less instinctive, may be dulled by living continually in an inartistic environment.

A room exists first of all for use, and in order to fulfill its function perfectly certain things are needed in it. A bedroom is for rest and sleep, and must therefore have something on which one can rest comfortably. A dining room is the place in which to eat, and must be provided with tables and chairs. And not only must each individual piece cater to the physical comfort of the people in the room, but the things should be so arranged that the room forms a beautiful unit when finished. This introduces a third element, namely, mental comfort. Rugs and furni-

ture placed at all sorts of angles on the floor give one a sense of restlessness. An isolated picture on a large, bare wall is cold and meaningless. An exhibition of silver on the sideboard may make one wonder if the cream pitcher was washed before it was used, or whether it still retains the micro-organisms which fell on it with the dust.

With function and fitness can be combined artistic qualities; but no matter how artistic in itself, a thing must be useful to be truly beautiful and decorative. The usefulness may consist, of course, in introducing a required color into any scheme of decoration. With regard to the decoration of any room, or anything in the room, it is important to remember that whatever interferes with its function or usefulness is not true decoration; it is rather ornamentation. A chair back may be beautifully carved but extremely uncomfortable to recline against. Such a chair neither caters to the physical or the mental comfort of the user, and the so-called decoration is really "ornamentation which exists to exploit itself at the expense of the thing upon which it is applied." If

ornament becomes apparent as an addition, it loses its decorative quality and tends to become ostentatious and vulgar.

Another important point to remember is that there may be in any room a number of things each beautiful and decorative in itself, but which lose their beauty and decorative qualities owing to their background, or to their nearness to one another, or to their inappropriateness.

Color and how it should and should not be used

Possibly of all the qualities which go to make artistic surroundings, color is the most important and the most personal. A knowledge of the meaning of color, and how, and to what extent it can be used, is of the greatest importance in the art of home decoration. The three colors yel-

low, red and blue are primary colors. If equal quantities of pigments in these three primary colors of normal tone — that is, of the tone as seen in the spectrum — are fused together, the result is gray. If equal quantities of normal yellow and normal blue are mixed, the result is normal green. Blue and red produce purple; and red and yellow produce orange. Green, purple, and orange are the binary or secondary colors. These facts can be expressed by a simple diagram like that shown in Figure 3.

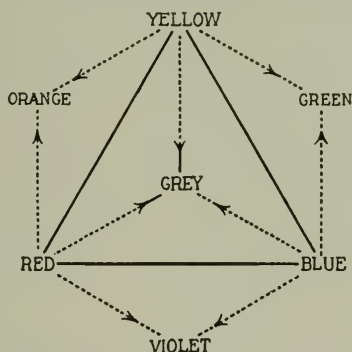


FIG. 3. PRIMARY AND SECONDARY COLORS

If in combining yellow and blue, more yellow than blue is used, the result will be yellow-green; if more blue than yellow is used the result will be blue-green. Thus by combining two primary colors in different amounts, we can get a great number of different "hues," a few of which are represented on the outer circle of the color chart. Since yellow, red and blue, when fused in equal amounts, produce gray, and since red and blue produce purple, yellow and purple produce gray, or neutralize each other so that there is no apparent color. The color tones which are opposite to each other in the color chart, and which

neutralize each other when fused, are termed "complimentary colors." If more yellow than purple goes to make the combination, we have gray-yellow (citrine). In the same way we have gray-red (russet) gray-blue (slate), gray-orange (buff), gray-green (sage), and gray-purple (plum), as shown in the accompanying color chart. These represent only a few of the many hues and tones which can be obtained.

Since the background of a room must be less intense than the objects which are to be shown against it, the slightly grayed hues of the twelve colors shown in the outer circle of the color chart are the most useful ones for backgrounds in decoration, and the normal primaries and binaries — hues which are forceful — are most useful to introduce accent and variety, and to emphasize.

The meaning of color

It is well known that certain color tones produce certain impressions in people, and therefore express, consciously or unconsciously, certain qualities; and colors can be used to the best effect only when their meaning is fully grasped.

Yellow gives the effect of light and brightness, and of sunshine. It makes a

Red (not vermillion, which is really a red-orange, but rather a crimson) suggests warmth and life. Red-orange may suggest excitement or irritability. Red is therefore rather a difficult color and often very unsuitable to use in any quantity, but rose and the softer crimsons are useful, particularly if blended with other colors, in fabrics. Red used with discrimination may suggest hospitality.

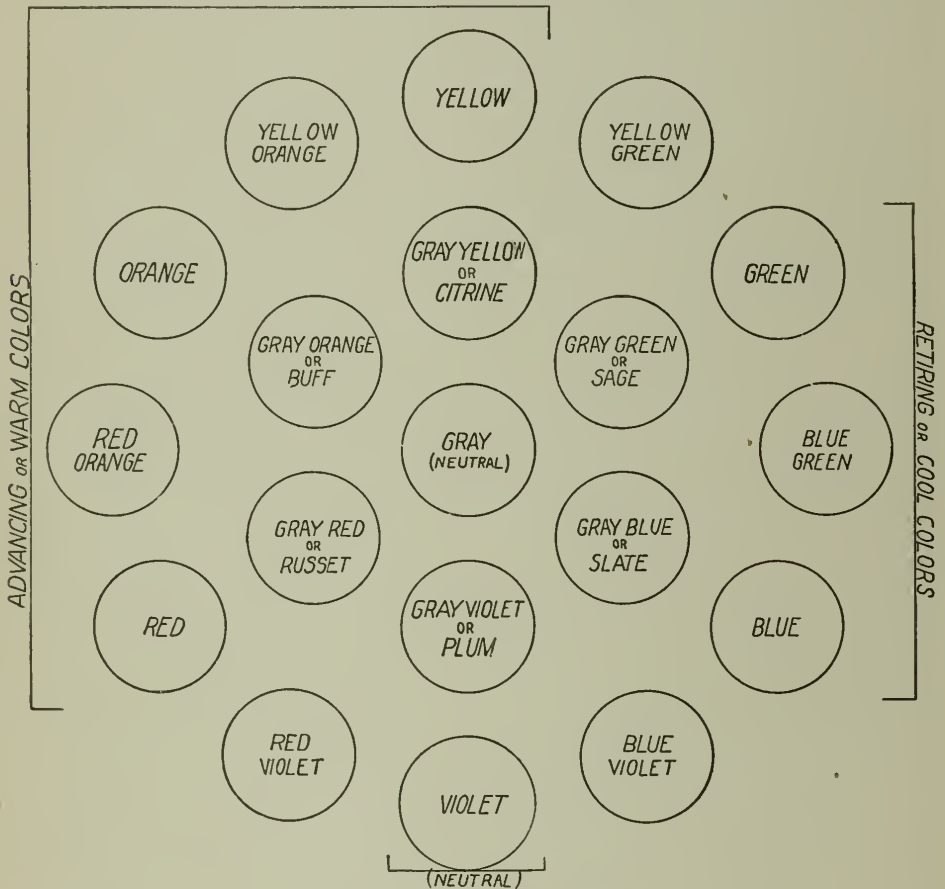


FIG. 4. KEY TO COLOR CHART

room cheerful when introduced in any shade. It is not necessary to use full, intense, normal yellow, but one of the more delicate tones of yellow, such, for example, as cream. If used in a strongly lighted room, it may produce a glare unless the quieter or grayed shades such as buff or tan are chosen, but at the same time, there should be enough yellow in the tan to prevent it from being dull or ordinary.

Blue is cold and non-aggressive and gives the sensation of coolness, repose, restraint and formality. The various tones of blue are often discordant and are difficult to blend. Blue of a certain shade and old ivory make a very artistic scheme of coloring; but the effect is cold unless relieved by a touch of rose or gold.

Green is a mixture of yellow and blue, and, unless the yellow predominates, is a cool, retiring color. In its slightly grayed

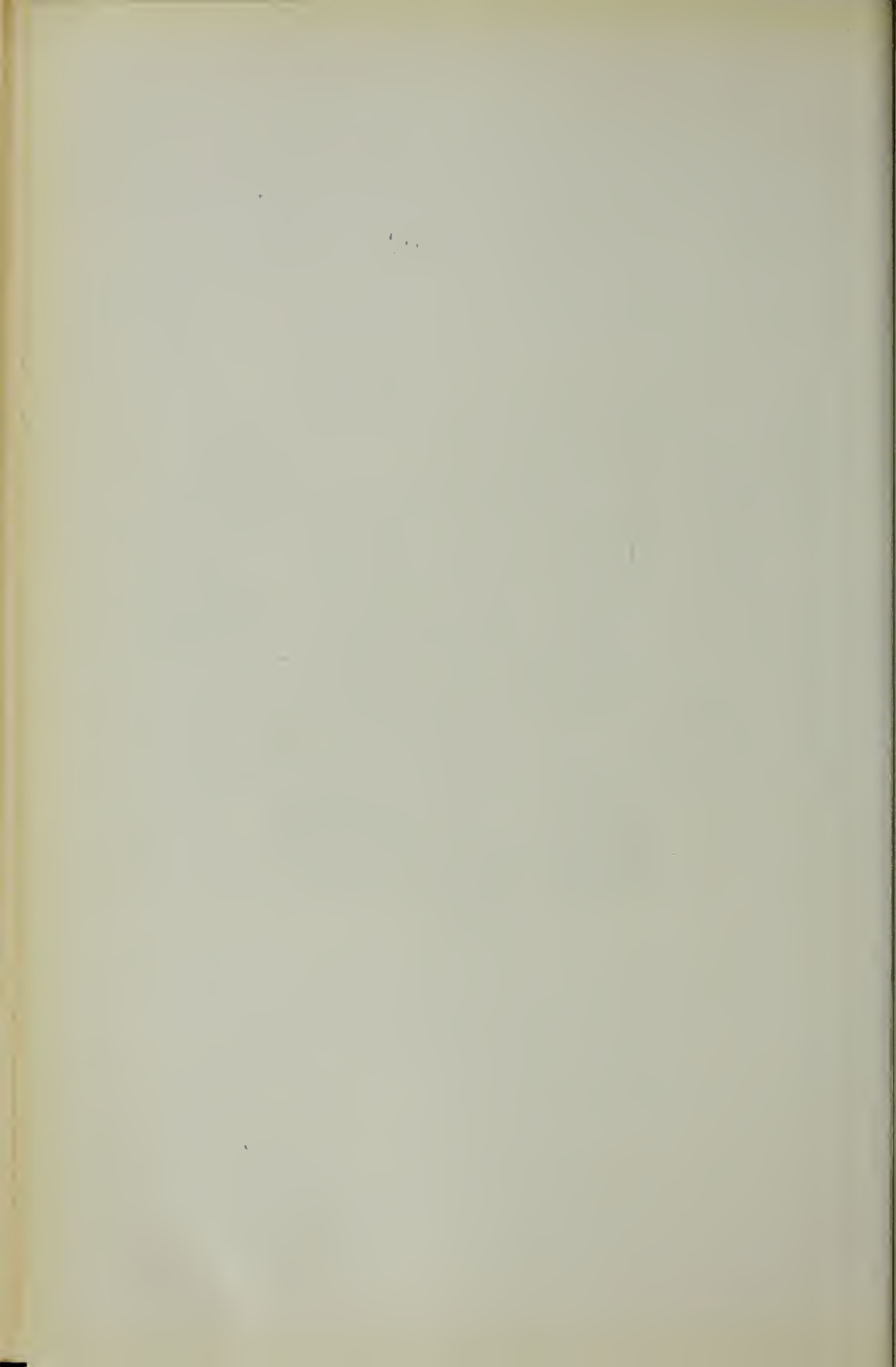
A DESCRIPTIVE COLOR CHART



THE OUTER CIRCLE SHOWS THE NORMAL, FULL INTENSE PRIMARIES, BINARIES, AND HUES.

THE INNER CIRCLE SHOWS HALF-NEUTRALIZED PRIMARIES AND BINARIES AS THEY APPROACH THE BACKGROUND POSSIBILITY. OPPOSITE TONES IN THE CIRCUIT ARE CALLED COMPLEMENTS.

From "Interior Decoration," by Frank Alvah Parsons
© by Doubleday, Page & Co.



tones, it is useful for backgrounds and in combination. It is a good color to use in hot climates, in country houses and for nervous people. Small amounts of vivid green are excellent for introducing accent in a color scheme.

Violet or *Purple* is a mixture of red and blue and as a rule suggests dignity, ceremony, sorrow and mourning. In its redder tones and lighter shades it can be used effectively in color schemes.

Orange is a combination of yellow and red, and suggests vigor and irritation. It is aggressive and destroys repose. Small quantities can be introduced to supply the required accent in a color scheme. In its grayed hues of brown, buff, etc., it is most useful as a background as it tones in very well with most wood colors.

The value of color

Apart from the actual color, the lightness or darkness of the objects grouped together for decorative purposes must be taken into consideration, namely, the value of the color. Bright pink, delicate blue, lavender, canary-yellow, and colors of similar value are associated with delicacy and youth and are therefore suitable for a girl's room or boudoir; while dark purple, crimson, dark green, and other similar shades stand for dignity, quietness, and maturity, and are therefore suitable colors for a reception room, library or a man's room.

Suppose an object of a pale delicate tint is introduced into a room which has otherwise dark, rich shades, the color may be correct but the tint so light that the object separates itself at once and becomes conspicuous.

The wall color and trim should have the same value even if different in hue. A large value difference attracts attention. The ceiling should be of the lightest tone, the floor of the darkest, and the walls midway, even if different in hue. If the wood floor is lighter in value than the walls, it can be adjusted by the use of dark rugs in the correct hue; but the lines of the rug must not be of such strikingly different values as to draw attention to them.

Curtains can be in stronger contrast to the walls than the trim is, as they are meant to be decorative and emphasize the structure, but they should not be in very great contrast. White curtains are suitable only if the wall, ceiling and furniture form a white or very light color scheme. If it is desired to use white curtains close to the window, the over-curtains may be selected in a color to tone in with the room's general decorative scheme.

The same idea is carried out in the framing of pictures. If a brown sepia photograph has a white mount and a dark frame, there is more contrast between the frame and mat than between the mat and picture, and therefore the eye is attracted to the frame rather than to the picture.

Harmony and variety

The whole idea of a home is restfulness and comfort, and restfulness can only be accomplished if each individual room makes a beautiful unit; and since each room is only a part of a whole, there must be unity between the rooms forming the whole. At the same time we must have a certain amount of variety and interest, otherwise there is dullness and monotony. Suppose a room has walls of a quiet tan color, and that the woodwork of the furniture keys in with the walls, such a room is drab, dull, monotonous. Introduce, however, a bowl of nasturtiums, or an orange colored vase, as an accent, and the room becomes more cheerful. Introduce blue of the correct shade (an opposing accent), and this is as emphatic as the orange (or related) accent. All harmony without relief is bad, as also is all relief without harmony.

To introduce unity with variety between a number of rooms, the whole can be keyed together by using slightly grayed tones of one color, say of yellow and orange, as backgrounds in the various rooms, that is, tints of cream, buff, tan, brown, etc., the tones varying considerably where the rooms do not communicate; and then introduce different dominant colors as accents in each of the various rooms.

Shape and size: the harmony of line and form to make unity

Besides harmony of color we must have harmony of line and form to make unity. The rule of harmony of line is most often violated by placing the rugs obliquely on the floor. The result is restlessness. Usually the furniture, cabinets, tables, etc., should be in harmony with the floor lines, though deviations may be made for a purpose, such as grouping chairs, desk, etc., conveniently for reading, writing and other recreations.

Shapes and forms which are alike become harmonious. A vertical, oblong picture fits into a vertical, oblong wall space and creates a feeling of harmony if the size is good. A square picture on an oblong space is less pleasing. Medallions and various shapes in rugs are often unrelated to the shape of the rug. In that case they should be so subdued in outline that they are scarcely discernible. A square cloth on a round table is less harmonious than a round cloth on a round table. Draped window curtains are another example of violation of this rule and are usually inartistic. Sizes must also be consistent. Large furniture in a small room or a huge design on the tapestry of a small chair do not conform to the principle of consistent sizes.

The problem of furnishing or refurnishing a house involves many considerations. No single object should be chosen for its value alone. It must fit into a scheme of decoration. And no single room can be considered only as a unit, but as a part of a house. Each room must be furnished

with a clear understanding of its functions and each thing must be chosen remembering what room it is to be in and with what other things it will be associated. When once the idea of the whole house is evolved, then it may be possible to make use of some things successfully. Whenever possible, the new scheme should be planned remembering what we already possess — but our present possessions should not have too much influence, for they can be gradually changed and improved. Whatever is retained should be beautiful and suitable, and not kept merely because it happens to be "Jacobean" or a "Chippendale" if it will not fit into the proposed scheme, or if it is not beautiful in itself. Make up your mind what you want your room to express. Determine what is necessary and buy it as opportunity arises. Never buy what is not needed and do not buy merely to fill in a space, but wait until the exact thing is obtainable.

Although the principles of color, form, and harmony should be followed in the main furnishings, which are too important for personal feeling to interfere, personality is shown in the smaller articles, — the selection and framing of pictures, the bowl of flowers, or the pieces of pottery. The room when finished should be a unit "to which nothing can be added and from which nothing can be taken without interfering materially with the idea itself," and everything in it should conform to the standard set by William Morris when he says: "Have nothing in your house that you do not know to be useful or believe to be beautiful."



Morgan Photo Service

DOUBLE BUNGALOW WITH GARAGE AT LOS ANGELES

PLEASING TYPES OF PACIFIC COAST HOMES



AT SAN DIEGO



AT LOS ANGELES



IN SANTA BARBARA



IN HOLLYWOOD



BOTH THESE ARE AT SANTA BARBARA



IN SAN DIEGO



STREET IN ALAMEDA



STRIKING ROOF AT PORTLAND



A CORNER IN SEATTLE

Photos by Lee N. Passmore, Charles Alma Byers, Morgan Photo Service, Columbia Commercial Studio, Pacific Photo and Art Co.

SIR ISAAC NEWTON SEES AN APPLE FALL



One of the great days of the world was that on which Sir Isaac Newton reached the conclusion of his frequent meditations on the question why things fall to the earth. That conclusion was the realization of the tremendous law of gravitation, by which all things are held in place, every particle of matter in the universe attracting every other particle with never-failing force.

UNITY IN MULTIPLICITY

The Mighty Scheme in which Stars and Continents and
the House you Live in Are Held together as One Whole

LINKS THAT BIND US TO SUN AND STARS

WE have now completed our preliminary survey of what, without having exhausted the meaning which the word conveys, we have agreed to call the universe. We have put the earth in its place, and found it to be one of the company of planets dependent on the sun which is itself but one of countless other suns, called stars; and we have looked into the atom, and found it to be an atomic system, into the ultimate depths of which we cannot pierce, any more than into the ultimate reaches of starry space. Having glanced thus without and within, we have obtained some idea of what we are about to study; but meanwhile we have been making the most gigantic assumptions, handling the most colossal ideas, without minutely examining or fully verifying them. The idea of a universe is, in part, the idea of a company of worlds, worlds too far for the telescope, worlds too small for the microscope, but it is vastly more.

For instance, we have been calmly taking it for granted, hitherto, that our first study of the skies, and our first study of the inwardness of matter, both have to do with one and the same kind of thing. In a word, we have assumed, without any rigorous proof, the idea of the universe as a single whole. This assumption, however, is not unfounded; all science goes to prove it; all science makes progress by adopting it.

However free and original and critical our minds, we all run a risk of taking for granted the ideas and customs and institutions which we discover around us. The idea of the universe as a single whole is in this case at the present day. All who have looked into these questions at all

find this idea accepted, established, unquestioned; so much so that they often accept it without really knowing they have done so. They speak of nature and the laws of nature and the universe without realizing how very much this involves and how very distant these ideas are from those that governed the thoughts of most of our ancestors and still govern the thoughts of many of our contemporaries. The concept of the unity and constancy of nature, ever working out its multifarious and multivariied effects according to fixed principles and unchanging processes, lies at the very foundation of science. The abandonment of this concept would render impossible the intelligent pursuit of the very object of science, which is to observe and examine the phenomena of nature for the purpose of coördinating and systematizing them by reference to their causes as a principle of unity; to abandon, therefore, the concept of the constancy of nature in its operations would be to give up science and to fall back into superstition—which assigns effects to inadequate, arbitrary causes. Superstition then is a crime not only against religion but against science as well.

The anti-scientific or superstitious idea of things regards them as a chaos, having no internal principle of order and unity. The scientific idea is that of a cosmos; and if one of these views be true the other is false. The chaotic view has been that of the overwhelming majority of all mankind in the past, and it is the majority view, in some form or another, now. It does not regard the universe as a Universe or a United Whole, but as a Multiverse, or a Scattered Many.

The real difference between the wise and the foolish man

Since it is, according to this view, not one, but many, its parts being, therefore, not parts of one another, and not interdependent, there is no certainty in the happenings we survey, and in the happenings of which we are the victims. That is not to say that superstition and ignorance go so far as to deny that things have causes. However ignorant or mad men may be, they never suggest that events happen uncaused. The difference between the wise and the foolish man is in the kind of cause they believe in. The man who has wisdom says that things are a universe, a cosmos, a great whole which he calls nature, and he declares that the causes which work the material effects we witness, and those we do not witness, are in the nature of things. He declares, further, that causation is universal, because the universe is all-of-a-piece; and he approves the fine lines of the poet —

Thou canst not stir a flower
Without troubling of a star.

To this view we shall return, and, having returned, shall never leave it for a page or a line to come — unless we there abandon science and are false to our task.

The way in which the savage looks out upon the world

But before we consider it, and show how modern discoveries, such as those we have already looked at, bear upon it, we must try to understand a little better the chaotic view of things which science has replaced.

For convenience, we may talk about "the savage." Our remarks may apply to the most fashionable and exquisite of modern ladies, visiting the palmist, the crystal-gazer, and the necromancer; nor is it our present business to ask what proportion of modern people are merely savages who have adopted the dress of civilization. The warning is necessary, since the accepted way of talking about "the savage mind" blinds us to some of the most staring facts of the "modern mind," and the insistent arraignment of the puer-

ility of the "superstitious mind" makes us forget the frequent intolerance and credulity of the "scientific mind"; both extremes are about equally unworthy of the true dignity of our God-given "human mind."

The savage, then, in his birthday suit or "faultless evening-dress," as the case may be, looks upon things as partly rational and orderly, but mainly directed and caused in quite another way. What he knows and sees and understands he regards as rational. He repeatedly notices that water wets and fire burns. Such happenings he accepts as orderly, and, indeed, makes as good a science as he can of them. In such cases we are all agreed everywhere.

Two views of the universe that are mutually exclusive of each other

But beyond such cases as these, where only one theory is possible, the savage thinks otherwise. Everything which is not straightforward and under his nose he looks upon as miraculous, and due to the arbitrary wish of invisible beings. Thunder and lightning are the voice and bolt of angry Jupiter. Disease is but the revengeful work of some un placated demon. An eclipse is due to the quarrel between the god of the sun and the god of darkness. An earthquake is due to a nightmare and uneasy sleep of the great dragon who lives underneath us and supports us. Man's life, his successes and his failures, his goodness and his badness, are determined by the configuration of the planets at the time of his birth; the length and form of the lines in one's palm is the sign manual of one's lease on life or hope of felicity. A rabbit's foot is almighty in driving off all manner of ills, and a glance from the "evil eye" is powerful enough to destroy health and happiness. Instances of such superstitions are as numerous almost as mankind; they can be drawn from any age and any people.

It is clear that between this chaotic view of things, and the view which states that the universe is a unity, that causation is constant, consistent, universal, there is an insuperable barrier. To be scientific

we must give up all superstition; we must hold firmly and clearly to our view that the universe is a mighty, consistent whole, however diversified may be its related parts; we must be persuaded that the only way for us to control the ordinary course of physical events is to learn those conditions and principles of their causation which we call the laws of nature and to act through those laws. And we shall have but a poor understanding of those laws if we do not soon perceive that if they are truly natural they are therefore divine; divine indeed not in themselves but in their origin from and their dependence on God, the Author of nature. It is He who, by giving to things the very nature they have, has fixed the orderly course and the changeless efficacy of nature's laws; and to Him alone can belong the power or the right of derogating from them. To expect miracles to be the rule of our experiences would be both unscientific and superstitious, to deny the possibility of miracles altogether would be both unscientific and irreligious. This extremely brief consideration of an almost inexhaustible theme seemed necessary if our study of the world was to proceed without violating either the just demand of science for constancy in nature on the one hand or the equally just demand of religion for an acknowledgment of the power and providence of God, the Author of nature, on the other hand.

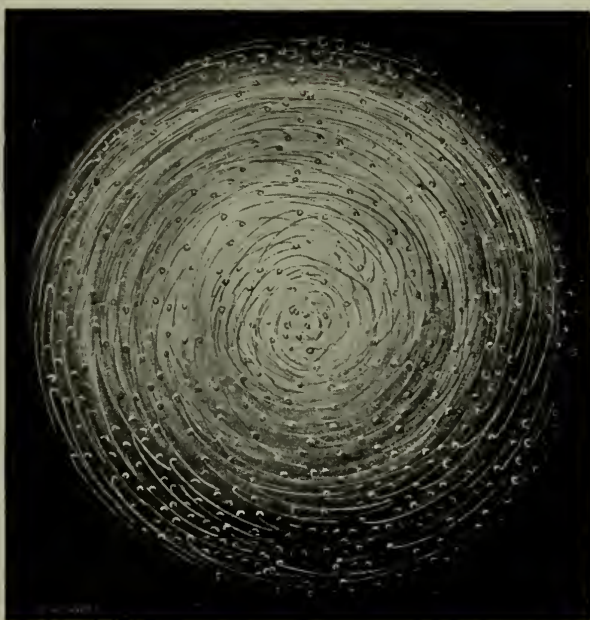
And now let us survey the evidence which teaches us that the magic carpet we call the universe was woven by one Maker, and is a perfect and single whole, not-

withstanding the number of its threads, and their variety of direction and color.

Consider, first, the company of worlds. What evidence have we that they are a company, in the full sense of the word? Why should we not suppose that they are all independent? What evidence is there that they form parts of a whole? We see no bond between them, no chains or ropes, and we do see that they move in all manner of directions, at all manner of speeds.

There are friends who rule and are ruled by one another, who cannot distinguish

between their own wishes and each other's, and who are a million times closer bound than any bond of flesh could hold the Siamese twins. They, too, may not move in the very same circle! Just so we learn that the stars and planets, having no visible bond, are yet bound together, and influence each other's form and structure and movement, without one moment's intermission throughout all the ages of their existence.



AN IMAGINARY PICTURE OF AN ATOM

No longer is it believed that the atom is the foundation-stone of the material universe, unbroken and unworn from the Creation; for we know now that the atom has within it a marvelous structure of smaller component parts, and is endowed with a supply of internal energy which is believed to be sufficient, if we could only once unlock it, to do all the work of the world for us.

"Stars and planets," we said, but that feebly expresses the truth. Newton declared that every particle of matter in the universe attracts every other particle with a certain constant, never-failing, never-varying force, which we call gravity. The couplet about the flower and the star is therefore literally true. Stars, planets, moons, comets, shooting-stars, rock, water, air, all forms of matter everywhere, are bound together, each atom to all other atoms, and all atoms to each, in a bond which utterly defies every attempt to modify it in any direction or degree. On this

one ground alone, having regard to all the evidence we can obtain — no mean quantity today — we are entitled to say that the universe *is* a universe. Newton saw an apple fall, and argued thence that the moon must similarly tend to fall to the earth, and thence that the earth must similarly tend to fall to the sun. When at last he was satisfied that his law included the whole solar system, our sun and its planets, he went beyond the evidence, and declared that all matter everywhere attracts all other matter. He had no right to do so but one: the right given him by his faith that the universe is one, and that what is true of the sun must be true of every star.

Only long after Newton's day was it possible to obtain evidence that the law of universal gravitation is what it asserts. Auguste Comte had, indeed, declared that by no possibility could men ever ascertain whether, at the inconceivable distance of the stars, gravitation is at work. Nevertheless, the evidence has been forthcoming; and astronomers have been able not merely to find the evidence, but, by observing and measuring the disturbances in the motion of a bright star, to prove the existence and compute the mass and the distance of a dark star, never to be seen by the eye, but yet known, weighed, and placed, by its gravitational action on its bright neighbor.

The case of the star Algol is a good example. "Algol" is the Arabic name for Demon, given to this star because the Arab astronomers could not account for its variations. The spectroscope has now proved the existence of a companion star which eclipses Algol in two days, twenty hours, forty minutes and fifty-three seconds. The diameter of Algol is believed to be about 1,120,000 miles — one-third

larger than our sun, and the diameter of Algol's companion, the dark star, is estimated at 840,000 miles, or nearly as large as our sun. Although this body has never been seen by mortal eye at this inconceivable distance, its existence is undoubted, and we owe the discovery to the law of gravitation.

That is satisfactory from the point of view of those who seek to prove that the universe is a universe, and that its laws are verily uniform and universal. But just within recent years the twentieth century has succeeded in obtaining evidence of action in the sky which renders the universal character of gravitation far more important still, and which we can only hope to understand by looking at it in the light of gravitation. Our business



WEIGHING A STAR THAT HAS NEVER BEEN SEEN

The law of gravitation, by which all things are held together, has enabled men to prove the existence of a star that no eye has ever seen. The light of the fixed star Algol diminishes every few days, and this is now known to be due to an eclipse of the star by a companion which has never been seen, though it has been weighed and measured and its place is actually known.

here is only to quote the outlines of the new discovery, and they may be easily set down. We find that the "fixed stars," so called, are all in motion, and that their motion is orderly. It varies in direction in each case, but on the whole its motion, so far

as the stars we can observe are concerned, is mainly in two opposite directions. J. C. Kapteyn of Göttingen and A. S. Eddington of Greenwich have demonstrated the existence of these two streams — which a famous astronomer, by a most illegitimate and unscientific use of the word, has called "two universes." They are not two universes, but two halves, or parts of the universe. As they flow through and pass each other, members of the two streams may collide. Such collision would have tremendous consequences, and may be the key to the history of many individual stars — their making and heating, and cooling and destruction. All this we must later study. Meanwhile we note the enormous importance of gravitation among the stars.

Mathematicians have calculated the chances of collision between stars moving at random, or in opposite streams, but when their reckoning is made they have to remake it, since each and all of these stars are attracting each other. There are many collisions in our city streets every day, when drivers seek to avoid and thus repel each other: how many would there be if they attracted each other? It is evident, therefore, that if we are to allot to stellar collisions any large importance in the making of stars, and ever new stars, throughout the ages, we must increase our respect for the law of gravitation, which must surely increase the number of such collisions; and we shall be prepared to discover that this law, working everywhere, is not only one of the proofs of the universe, but one of its never-weary architectural forces, helping to make and remake it from age to age.

It must not, however, be supposed that only gravitation justifies us in looking upon the stars as parts of a mighty whole. On the contrary, our study of light and heat waves teaches us that here also are forces and laws whose action is universal, and reacts between star and star. Within the last few years it has been proved, for instance, that a force called "radiation-pressure" acts everywhere and brings into relation all parts of the universe. But this discovery about light and other kinds of radiation is insignificant compared with other evidence which sunlight and starlight afford that the universe is one.

This evidence, also, can only be outlined here, but it corresponds as perfectly to the inward survey which we made of matter as the evidence of gravitation corresponds to the outward survey we made of the heavens. When we looked as far as we could into the inwardness of things we soon encountered something called — though we now know it should not be called — the "atom." Atoms, we learned, are of some eighty kinds, each kind making up one of the elements, such as carbon or hydrogen or sodium. We learned further that, in regard to their internal structure, these atoms are composed of moving units, called "electrons."



TWO DARK SUNS APPROACHING ONE ANOTHER



THE SUNS ABOUT TO COLLIDE



THE TWO SUNS IN COLLISION



THE SUNS "GRAZE" AND PASS ON



THE EFFECT OF THE COLLISION



A NEW FIERY WORLD EMERGES



THE NEW STAR SHINING IN THE HEAVENS

These drawings illustrate Professor Bickerton's theory of the birth of new stars. It is believed that stars occasionally collide, each leaving behind a portion "grazed" off in the collision. This may become a new star, shining for a time, before its light dies out

It has long been known that when any element is heated enough to give out light, that light is peculiar to the element in question, so that any element can be recognized or detected by the light it gives, no matter what distance the light has traversed. Later on evidence was found which goes to show that the character of the light given out by any atom depends chiefly, if not solely, on the number and movement of the electrons in it. But now we can appreciate one of the most wonderful of all proofs that the universe is really one — the proof that it is throughout constructed of the very same materials.

may be deceived, but there is no forgery in the skies, and the signatures of the atoms are unmistakable. We know that there are sodium atoms in the sun, for we have only to decipher sunlight closely in order to read their names.

The application of this principle speedily shows that the elements we have identified on the earth are the universal elements which compose, in varying proportions and combinations, all heavenly bodies as well. To mention only the most recent instances, the peculiar element helium, found in the sun, by its characteristic contribution to sunlight, was later found in an earthly mineral called cleveite, and later



THE MARVELOUS ENERGY THAT WILL BURN THROUGH ICE AFTER COMING 90,000,000 MILES

The sun is a marvelous manifestation of energy. Its heat rays, after a journey of over ninety million miles, reach the earth with their energy unspent and still able to light a fire if directed through a piece of ice rounded like a magnifying-glass.

A little common salt, made luminous, as by holding in a flame a wire that has been touching it, gives forth a yellow light. This light can be precisely described, measured, and analyzed; and it is the characteristic light of sodium, the metal which goes to make up common salt. No sooner do we attempt to analyze the light of the sun in the same way than we find that it is partly made up of the same arrangement of light-rays as we know to be characteristic of sodium. We are much more certain that sodium atoms, whose light-autograph we know so well, are in the sun as well as in common salt than any one can be that a signature before him was written by the man whose name it spells. The handwriting expert

still was proved to be one of the elements produced by the breaking up of the element called radium.

This last sentence reads like a contradiction in terms, and it is indeed in need of explanation. The key to it adds incalculably to our idea of the oneness of things, and it is yet another of the achievements of our century. We have already learned that atoms are not really atoms, but have parts, and therefore that the elements of which they are the units are not really elementary. We have discovered that every atom consists of units, called electrons, arranged in certain orderly ways or in a kind of atomic system, which has its own center of attraction, which is called its nucleus, the combination being very

probably comparable to the sun and the solar system. The great fact which has now to be stated, and which may be said to surpass anything hitherto known as proof of the oneness of things, is that all electrons are the same, no matter where we observe them. All the electrons in a given atom are the same. They are one and the same in all atoms of a given element. They are the same in atoms of different elements. They are the same in atoms observed on different worlds.

The so-called "elements" really compounds of simpler units

Hitherto, somebody might have said, and many people did say, we had not found any one material which makes up all things, so proving that all things are one. On the contrary, we have found not one but over eighty different materials which we called "elements," of which we asserted that they could never change into one another, though ignorant men, we said, used to look for a "Philosopher's Stone" which should turn lead into gold. Our assertions seemed accurate, but lessened to some extent the oneness of the universe, which would have greater unity if it were made up of some one ultimate stuff, instead of eighty and more different stuffs.

Radium, the revealer, and the work which it has suggested and guided, have shown that the elements are really compounds of simpler units, called "electrons," grouped around their nucleus, and that these electrons are all everywhere the same. We have, therefore, all but reached the proof in demonstrable form that there is a simple stuff of which all things are made.

Chemistry and physics, and philosophy too, have long sought for this primitive, simple raw material of all things, and men have often thought that it was found. But this new discovery makes a new age in the history of human knowledge, by showing us the "one element" of which all material things are made. That element itself may yet prove to be not the ultimate matter of the universe at all, but a form of electricity modifying perhaps the primi-

tive ether; matter ever seems to dissolve more and more under our analysis, each step of which, though we thought it to be the final one, leaves us groping for something beyond, something which as yet we cannot grasp; but the fact remains that we have at last succeeded in tracing and tracking a universal *something* which is common to all the so-called elements, and all their millions of compounds, which compose the material universe. However much farther the journey be, and even though it should be endless, this is a great step into the heart of things.

Two somethings not easy to define which are undoubtedly real

It is possible to go even farther, and to recognize two *somethings*, not easy to describe or define, which are yet "universal things," and undoubtedly real. With the survey of these we may consider that our idea of the universe is adequate; and we may therefore go ahead with the detailed scientific study of what the universe is, and what it does. But these two things must be named first, and we must have some notion of what they mean. Without them, we cannot attempt any adequate study of the real structure and laws of the universe or even of a single movement or action on the earth or in the sky.

"Ether" is the name of one of these things: the "ether of space," it is often called, because this medium of extreme tenuity and elasticity is supposed to be diffused throughout space. Its existence was often denied in the nineteenth century; and though the beginning of the twentieth century found it universally accepted, a new school has again arisen to challenge its claims for a place in the universe; but these claims seem so imperative that we here accept the ether, whatever it is, as a reality, and a universal one.

The great vehicle of electricity and light and gravitation and heat

As modern science understands the ether, it is absolutely and continuously everywhere, and is the vehicle of the great forces and activities of electricity, gravitation, light, and heat, which mold and move the

worlds. What it is "in itself" we do not know, but we strongly suspect that, impalpable and invisible though it be, it is more fundamentally real than the matter we touch and see. If it be the necessary vehicle of electricity and of gravitation — which is suspected by the leaders of modern physics to be electrical in origin and nature — and if gravitation acts between all portions of matter everywhere, and if matter itself involves electricity in its constitution and internal structure — then plainly we can never escape from the ether, whatever part or aspect of the material universe we study; and its existence is one more overwhelming piece of evidence of the unity of nature. Contradictions, as they seem to us, and mysteries at present insoluble, the ether presents to our study, as we shall later see, but our business is to face difficulties, and believe that they are worth solving.

The energy which is in everything and travels everywhere

"Energy" is the name of the second of these two universal things, which we must name now because they contribute so powerfully to the idea of the universe as one united whole.

Energy is a comparatively new word in science, and its introduction and definition, by students of nature, was a great and important service to modern thought. It is yet another of those real things which cannot be seen and handled. We can define it only by its properties, by what it does; and this power to *do* is just what makes it. A great writer has expressed the view that the chief service of the last century to what is called "exact science" was its discovery of energy as a universal thing, and of the wonderful properties which it possesses, finally leading up to the magnificent conception of the Conservation of Energy, which we must proceed to study in our next chapter.

Here we are concerned with energy because it is a universal thing, and because its behavior proves the unity of the universe more abundantly than any evidence we have yet mentioned. Most householders are now familiar with the term

"units of electrical energy," and they realize that there is a measurable kind of power which they can turn into light and heat when they like, and that this electrical energy can also be turned into the energy of motion in the case of trolley cars and trains. Here is an invisible something, which is certainly real — the energy of the moving trolley car which hits you is no myth, though you cannot hit it back — and which can do all sorts of things and travel all manner of distances. The energy of sunlight, having traveled many millions of miles, can raise a blister on your cheek as readily as the energy stored in water may raise an elevator or the energy of gasoline may raise an airplane or drive an automobile.

The energy of the stars which enables us to see them

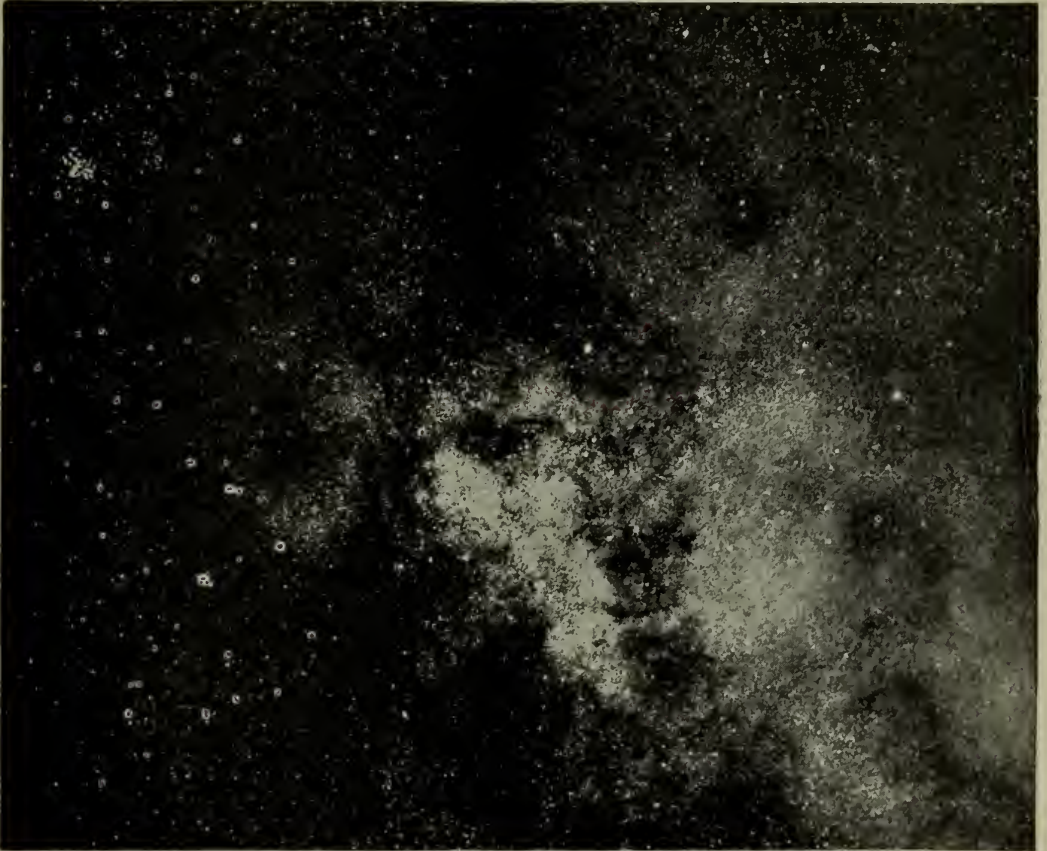
Here is an invisible, real something which does things; and when we study it we shall find that it has definite laws, never transgressed, not even by radium, as so many people supposed a few years ago; and we shall find, too, that its doings are universal, and that its powers can be transferred from any part of the universe to any other. Every star we see is sending energy to the earth; we could not see it but for the action of its light-energy upon the pigment in our eyes. That energy may have traveled many billions of miles before it reached our eyes, and may have taken thousand of years to come, but it is essentially the same thing as the light-energy of a match which we strike at arm's length.

What is true of light-energy, the form of energy we call light, is true of electrical or heat energy, the forms we call electricity and heat. It is true of the energy contained in all forms of motion, and the energy produced when we burn coal or explode gasoline. In all these, and in all other cases where anything happens in the universe — and something is always happening everywhere — energy is at work, and energy is really one and the same thing everywhere. The evidence is already sufficient to show that we are compelled to think of all things as having a true common bond, to think

of the universe as indeed a universe ; but we shall find this a thousand times clearer still when we study the law of the conservation or persistence of energy, which is the chief factor of all change, yet is changeless in itself.

We have spent only a few pages on a theme which has occupied the greatest of thinkers and writers for centuries past, but we have seen enough to be convinced of the true unity of the universe. This

In other sections we shall study such things as life and man and plants and nations and manufactures. All these things are part of the universe, and in so far as they are material they are subject to the same laws as matter. Gravitation is at work between the stuff of this paper and the stuff of the reader's eyes, and the stuff of the sun and the stuff of Halley's Comet ; the living branch of the tree droops under the weight of its fruit, and it is gravitation



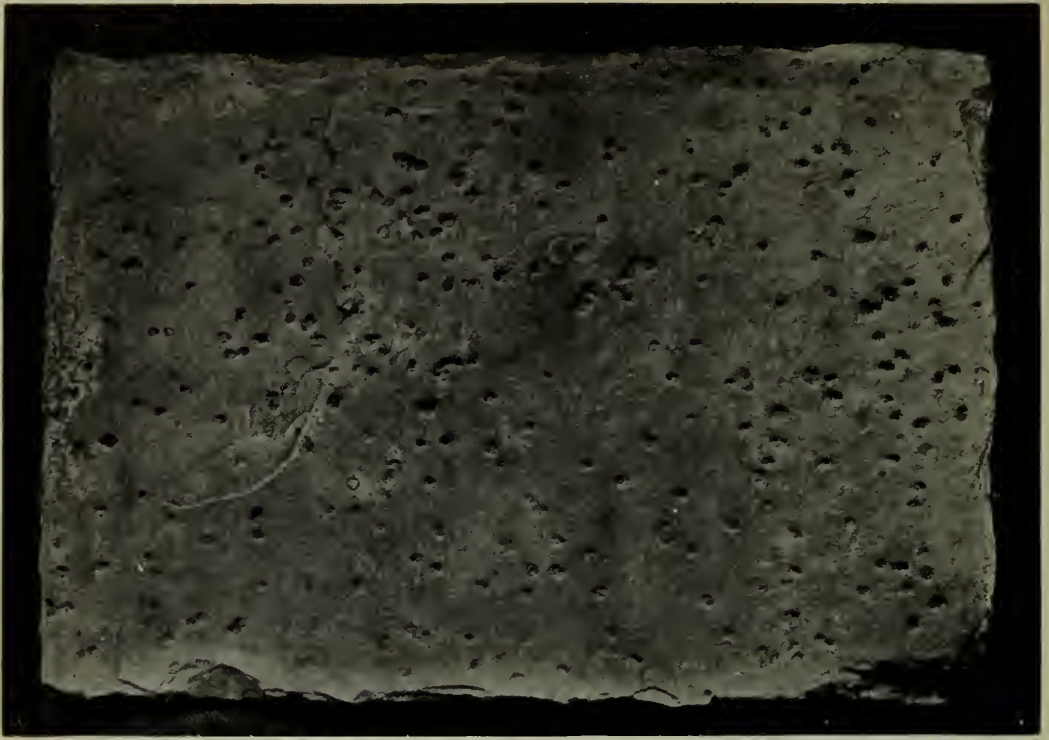
THE MIGHTY STREAMS OF STARS WHICH ARE FOREVER MOVING THROUGH SPACE

The early years of the twentieth century have made an important addition to our knowledge of the stars, which we now know to move in orderly systems, held in place by the very same law of gravitation which also holds in place the earth and all that is in it.

is not only a great result of science or knowledge, but it is the promise and the guide of future knowledge. If true unity exists in the universe, every fact has in it, if only we knew enough, the key to countless other facts: the study of what happens in a vacuum tube may give us the key to the history of the stars, and the observation of a falling apple may lead to our learning how the heavens themselves are balanced.

too that battles with the mountain climber and makes him halt in his upward journey. All these things, and all other things, are bound by that link and by many other links ; and if all these could be dissolved into their units we should find identical electrons composing them all, sun and paper, eyes and comet, branch and fruit, mountains and the body of man as well. In so far as we are matter we are brothers to the stars.

RAIN THAT FELL BEFORE HISTORY BEGAN



RAINDROPS PRINTED ON SANDSTONE MILLIONS OF YEARS AGO — THE LOWER ONES NATURAL SIZE
These two photographs show the marks of rain that fell in days before history began. The raindrops imprinted themselves clearly on sun-dried flats of mud by the sea, and on the return of the tide the impressions were covered by sediment, which preserved them, sealing them up in the slowly forming rock.

ALL THE WORLD ON FIRE

The Crust of the Earth — How Hard we Know it is,
How Thick we Guess it is, and How Old we Think it is

HOW LONG HAS THE EARTH BEEN SPINNING?

THE earth, as we suppose, with the aid of the nebular hypothesis, was at one time a hot molten mass. It is easy to picture the world in its present solid state, but it is difficult to imagine it a globe of surging, seething, molten metal.

At first there would be no crust. At first the whole surface of the world would be sea. And what a sea! Not a sea of blue water with a fringe of surf rolling in upon yellow sands, not a sea bearing white-winged ships on its bosom, but a seething storm of boiling, steaming lavas, pounded into monstrous waves by tempests of ponderous metallic vapors, whipped into fiery foam by the knout of iron sleet, scourged and scarred by the lash of the masses like stars.

Heavy would be this primeval sea, and there would be no moon to move it, but the sun would drag and churn it, and the atmosphere — which then must have exerted a pressure of 5000 pounds to the square inch, instead of fifteen as now — would plow and furrow it. There would be currents between the poles and the equator, for the cooler metal at the poles would sink, and warmer molten metal from the equator would flow in. No doubt cyclones and anticyclones would also arise, and drive before them the molten mass.

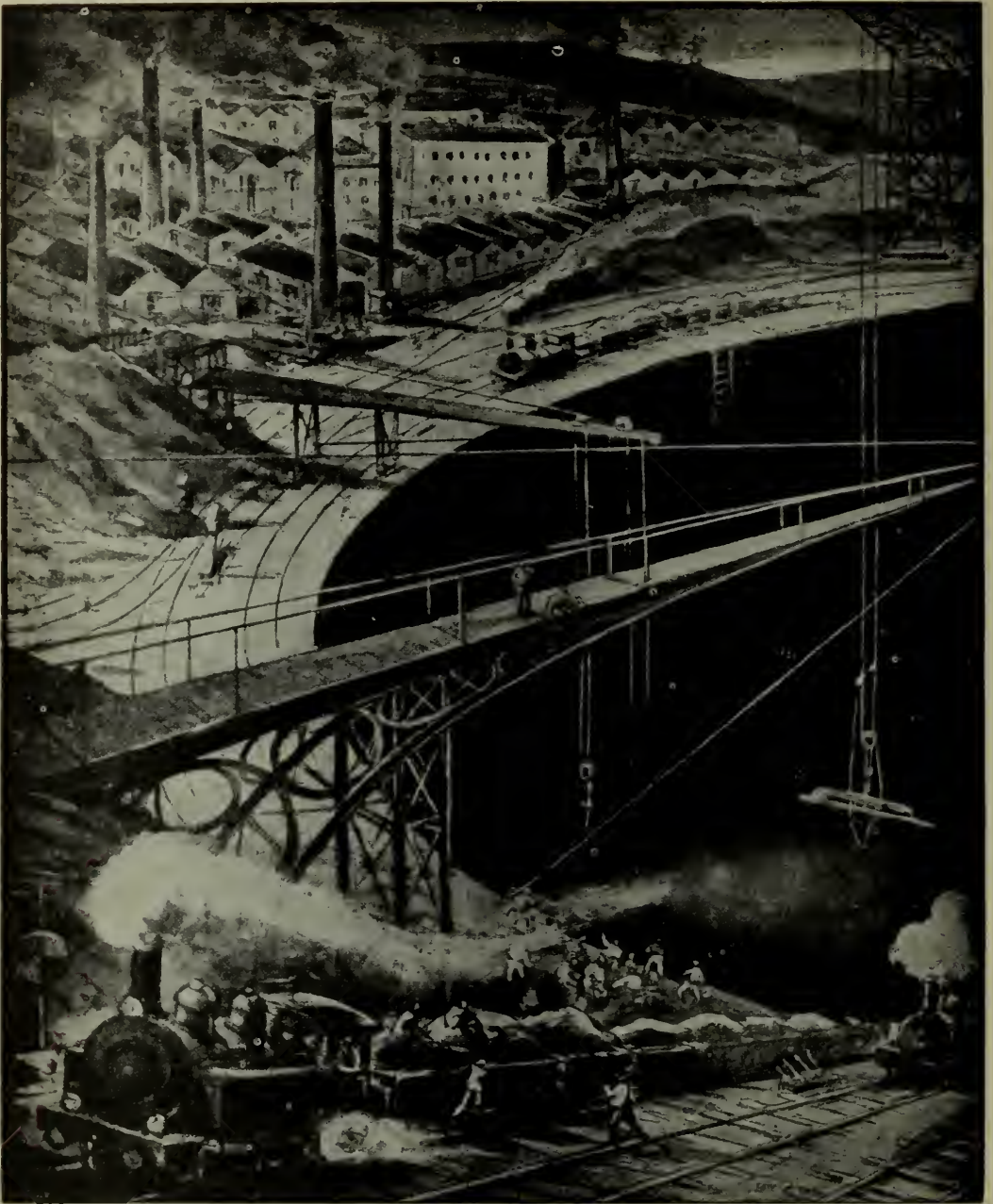
Over this weird wild sea unbroken night would reign, for the sun would be hidden by the heavy metallic vapors, and the only light would be the flashlight of the shooting stars, the glow of the fiery waves, and the flicker of the terrible primeval lightning. The rumble of the thunder, the thud of the ponderous billows, the splutter of the molten hail, the roar of the metallic

tempests, the sizzle of the falling stars, would create a perfect pandemonium. Such a Hades heat can make!

But heat is ephemeral; every hot body cools, whether it be a hot potato, or an incandescent fire-mist, or a glowing world. Age after age, heat radiated into space, and as it radiated away the great earth-caldron ceased to boil, and began to simmer. Cool currents fell, hot currents rose in the bubbling mass, and by and by, even as rough ice forms on a freezing lake on a windy day, so a wind-roughened crust began to form on the surface of the molten, steaming sea.

At this time almost all the water now in the sea would be in the atmosphere. A shell of water about two miles deep would be spread through the air, and would exercise a tremendous pressure on the surface of the globe — a pressure equal to solid rock 4000 feet thick. Accordingly, since pressure assists the consolidation of molten masses, the crust would begin to solidify at a very high temperature, probably a good deal over 2000° F. or at about 1200° C. Under such pressure, and beneath such a blanket of hot, damp air, cooling would proceed very slowly; but as the crust cooled it would contract, and the contraction again would cause strain. And the crust would be exposed to other strains.

It would be tugged by the sun and moon — supposing that the moon had come into existence then — and battered by the heavy atmosphere, and underneath it the hot liquid tides would surge and heave. Under such strain the crust would crumple and rumble, and quiver and boom, and

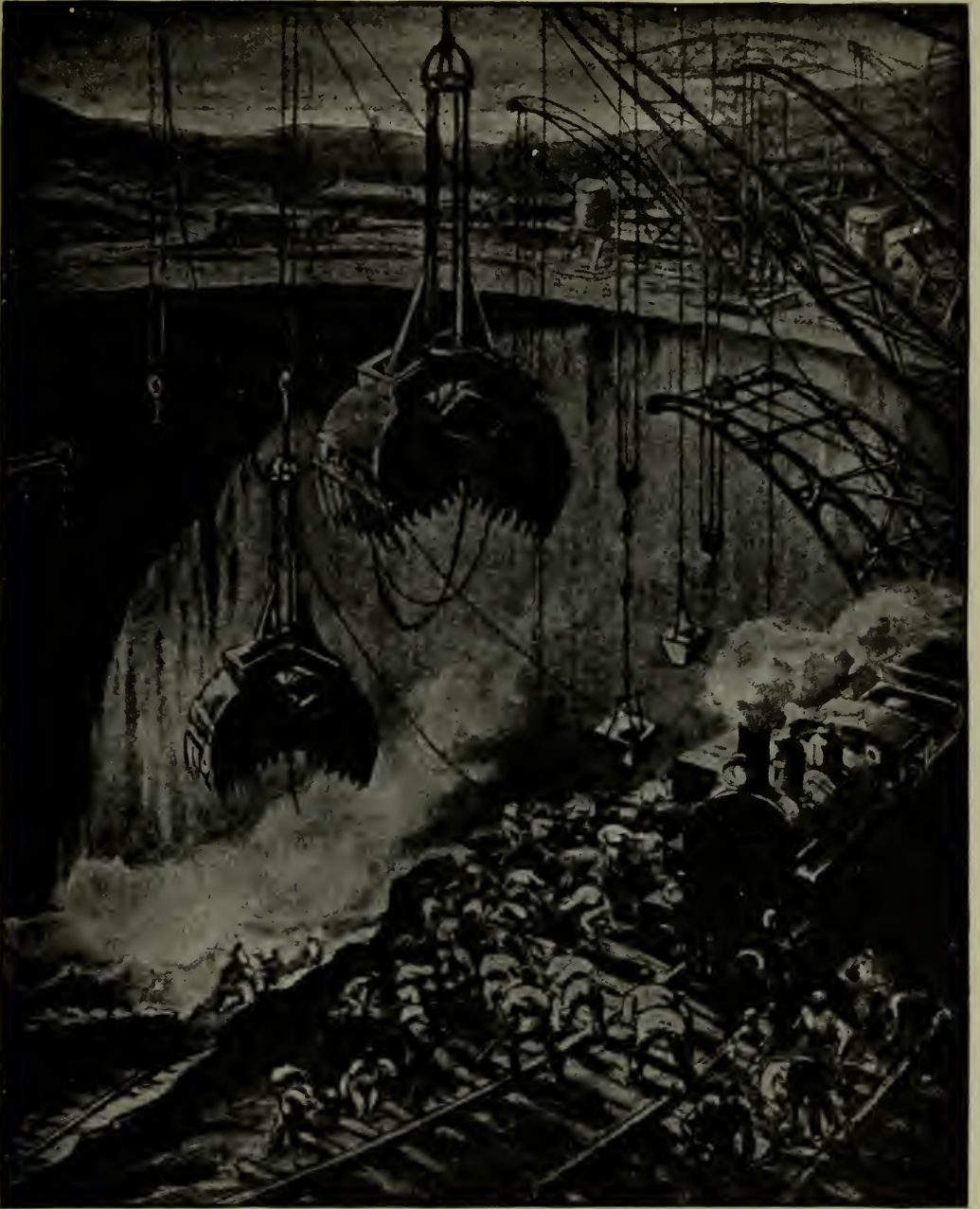


THE EXTRAORDINARY CONCEPTION OF M. CAMILLE FLAMMARION, THE GREAT FRENCH ASTRONOMER,

A distinguished French scientist with great imagination, M. Camille Flammarion, has suggested an amazing scheme for investigating the real nature of the interior of the earth. The deepest hole ever bored in the earth is just over a mile deep, but M. Flammarion suggests boring nearly five miles down. This huge cavern, with a diameter of nearly a quarter of a mile, would take many years to

finally there would be an earthquake and a volcanic eruption, and the crust would crack and crash like broken ice on a river in a thaw, its fragments floating on the steaming sea beneath. Again and again, no doubt, the crust would form; again

and again it would crack. It would be a time of earthquakes and volcanoes, of "glutted hell disgorging fiery spume." But by degrees the crust would grow stronger and stronger, and ultimately it would be strong enough to endure the



TO BORE A HOLE FIVE MILES DEEP AND 350 YARDS WIDE, FOR STUDYING THE INSIDE OF THE EARTH dig and would cost millions of money, but M. Flammarion suggests that it would be a scientific work upon which parts of the standing armies of the world might well be engaged. These pictures convey an artist's impression of the scene while the work is going on, showing the enormous cranes and "grab-buckets" which would run down into the earth to bring up the broken rocks.

strain of contraction. Then the earth would show an irregular surface, roughened and indented by the marks of many scars and of many badly set fractures.

As the cooling still continued, the water vapor in the atmosphere would condense,

and hot rains would deluge the world. As the world would then be much hotter than the rain, the rain would hiss as it fell, and would evaporate rapidly. But the rapid evaporation would hasten cooling, and in time permanent pools would form. What

a momentous event the first little puddle was! Who could have foreseen in it the mighty oceans of the world?

That the earth has now a solid and stable crust is self-evident. Sometimes it yawns and swallows an island; sometimes it shudders and shakes down a city, but, as a rule, it is certainly *terra firma*. When, however, we come to the question of what is below the crust we reach more debatable ground, and find much difference of opinion. Indeed, it is almost impossible to decide with certainty just what the condition of the central mass of the earth is. Let us look at some of the facts.



AN AMAZING EFFECT OF PRESSURE

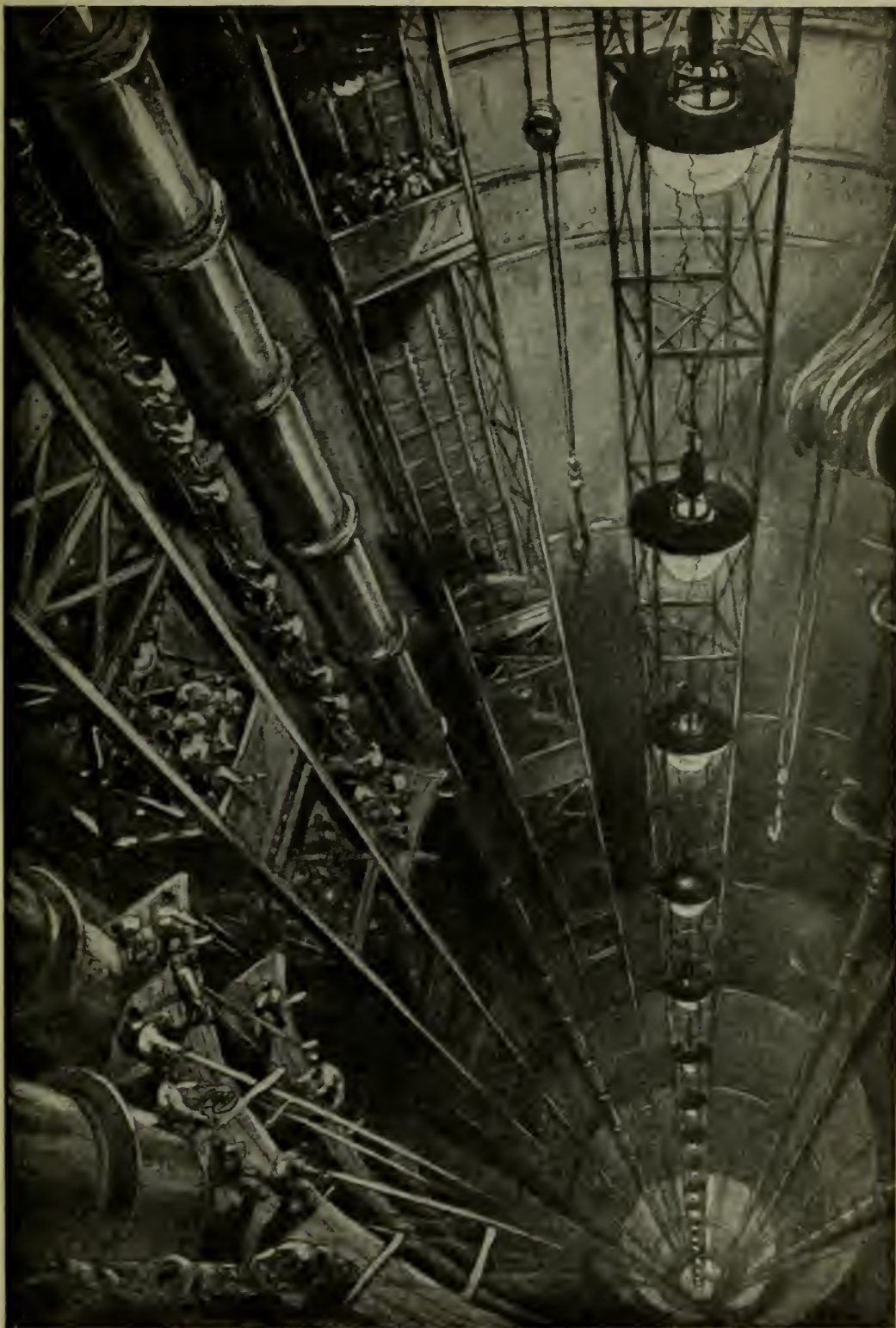
So great is the pressure of the earth that clay 1000 miles deep must be as heavy as iron, and ten miles down the pressure equals the force of the explosion in a 110-ton gun. This picture shows how a piece of soft moss penetrated into steel under the pressure of gun-fire, a cartridge having been fired immediately above it.

When we examine the temperature of the crust of the earth, we find that down to the depth of a hundred feet it varies according to the amount of heat it receives from the sun, and that at a depth of a hundred feet, just beyond the reach of solar heat, it retains a constant temperature of about 52°F . So far there is no suggestion of a hot interior. But when we penetrate deeper than a hundred feet we find that the temperature of the crust rises. The rate of the rise depends, to some extent, on the conductivity and chemical character of the rock, but, in general, borings show a more or less regular increase of temperature with increase of depth.

Of course, men have never bored far. One of the deepest bore-holes ever made is the well at Czuchow, Germany, which is a hole no less than one mile and 2068 feet deep — a hole, that is to say, thirty-one hundred feet deeper than the height of Vesuvius. But still deeper wells have recently been drilled in West Virginia; the Goff well was drilled to a depth of 7386 feet, and the Lake well, near Fairmont, had, on the 12th of June, 1919, reached a depth of 7579 feet; a cave-in on that date made farther drilling impossible. This was the greatest depth to which man had bored up to that time, and though it sounds like a deep hole, it is really only a pin-prick in the earth's skin, for it is nearly four thousand miles from the surface to the center of the earth. Mr. C. E. Van Orstrand, of the U. S. Geological Survey, took advantage of these deep wells to determine the rise in temperature and found it to be closely one degree Fahrenheit for each 69 feet below the sun-heated level in the Goff well and one degree for each 65 feet in the Lake well; that is, at the rate of about 80 degrees F. per mile. Some other experiments have shown that there are many exceptions to this rule, but it is generally established that the temperature increases at the rate of one degree for about every 60 or 70 feet of descent into the crust of the earth.

Between our feet and hot rock, then, is only a comparatively thin film of cool crust. Peel only two miles of rock off the surface of the world — a layer less in proportion to the mass of the world than its skin to the mass of an apple — and we should all be grilled. This is a remarkable fact, but facts still more remarkable follow. If the temperature of the rock thus increases, the heat must be flowing from still hotter rock deeper down, and we may conclude that even at greater depths the heat continues to rise, though perhaps not so fast as in the upper layers. We are constrained, therefore, to believe that the earth is still intensely hot in its interior — hot enough at fifty miles deep to fuse or to volatilize under ordinary conditions the most refractory rocks. Deeper still.

A SCIENTIST'S PLAN TO PIERCE THE EARTH



AN IMAGINARY PICTURE OF THE BORING OF THE FIVE-MILE DEPTH SUGGESTED BY M. FLAMMARION, THE FAMOUS ASTRONOMER, FOR STUDYING THE INSIDE OF THE EARTH.

the heat must become terrific. We may assume, then, that the earth still hoards in its interior a huge store of the tremendous primitive heat with which it is believed to have started. Strangely enough, however, even assuming this, we cannot venture to assert that the core of the world is molten. Pressure tends to solidify, and the core of the earth is under enormous pressure. Not only is it squeezed, as in a vice, by the contraction of the cooling surface layer, but it is compressed more and more under the load of superincumbent rock. So great is the pressure in the interior that clay at a thousand miles depth must be as heavy and dense as iron. Ten feet of rock means a pressure of fifteen pounds on the square inch; a mile means three tons a square inch; while ten miles means a pressure of thirty tons a square inch—a pressure nearly equal to the pressure inside a 100-ton gun when the cordite is exploded. Deep in the interior of the earth the pressure must be many thousands of tons.

The titanic forces that fight for mastery inside the earth

So that, though the heat in the heart of the earth is sufficient to melt or reduce to a vapor the most refractory rocks, we have no right to assume that the rocks are actually melted or vaporized, for pressure so prodigious may alter or counteract the effects of the heat. We have to decide, not whether the heat is sufficient to melt or vaporize rocks under laboratory conditions, but whether the heat can melt or vaporize rocks under such conditions of very extraordinary pressure as exist in the earth.

We know that pressure affects the melting-point of substances; we know that, under abnormal conditions of temperature and pressure, matter begins to react in abnormal ways. Potassium under ordinary temperature rushes about on the surface of the water, tearing oxygen from the water molecules, and setting itself on fire; but, as Professor Dewar has shown, "a berg of silvery potassium might float forever untarnished on an ocean of liquid oxygen."

When we exhaust a Crookes tube the attenuated matter left behind acts in quite new ways. Under great pressure steel may be made to flow like butter, and granite pebbles are found flattened like pancakes, yet retaining their crystalline structure.

Novel conditions, therefore, alter the customary behavior of matter, and here, in the earth's heart, we have most novel and abnormal conditions. We have two titanic antagonistic forces fighting for mastery—we have prodigious pressure tending to keep the rocks solid; we have terrific heat tending to melt and vaporize them. Which force, down in the obscure depths, gains the victory? We cannot say. It is true that the increase in pressure is not so great proportionately as the increase in heat, but that is not sufficient to decide the question; and, so far as the facts of heat and pressure go, the center of the earth may be either solid or liquid or gaseous: it may even consist of electrons—infinitesimal particles which behave neither as solid, nor liquid, nor gas.

The three theories as to what the inside of the earth is like

Consideration of the facts of heat and pressure cannot, then, decide the question of the condition of the earth's center. Nor are other considerations altogether conclusive. We find many facts suggesting solidity. It is certain that the earth *behaves* after the manner of a solid rigid body; it is certain that the crust must be as rigid as steel, for otherwise it would yield to the attraction of the moon, and show tidal waves. About ten years ago (in 1913) Michelson and Gale conducted at Yerkes Observatory a very accurate and complete investigation of the amount by which the earth yields to the tidal forces, and their results show that the interior of the earth is not viscous, but elastic and resists deformation as thoroughly as would an equal sphere of solid steel.

Again, the vibrations that are caused by earthquakes are transmitted as waves both round the superficial crust of the earth and through its substance, and it is known that the vibrations travel through the earth at the rate of ten miles a second.

But ten miles a second is faster than vibrations travel through steel, and that proves that the interior of the earth is more rigid than steel. Yet, again, mathematicians have shown that the *precession* of the earth's axis indicates solidity. The *precession* is due to the attraction of the sun and moon on the earth's equatorial bulge, and mathematical reasoning proves that this attraction would probably stagger the earth still more if it had a liquid center.

On the other hand, it is quite possible that liquid under great pressure might behave like a rigid solid, and the geological phenomena of earthquakes and volcanoes give some indication of a thin crust, a solid nucleus, and an intermediate liquid layer. But it seems more probable that the intermediate liquid layer is only of local occurrence in volcanic regions and does not constitute a complete shell of matter.

Whatever the result of the heat may be on the solidity of the earth, it is certain at least that the earth is a great reservoir

of heat, and this fact in itself goes far to confirm the theory of the earth's origin from nebulae. For if the heat be not derived from an incandescent nebula, how are we to account for it?

Is the nebula from which the earth evolved still giving out heat inside it?

It is true that the earth once rotated four times faster than it rotates now, that its retarded motion implies friction — such friction as is manifested in the tides — and that friction develops heat just as certainly in a planet as it does in a grindstone. No less than about fifteen-sixteenths of the energy of rotation of the earth has been thus converted into heat. But heat so produced would be found chiefly in the superficial layers of the earth, whereas the heat of the earth is focused in its center. No doubt frictional heat augmented and augments the native heat of

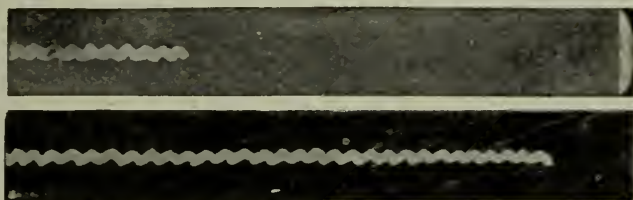
the earth, but in all probability the main source of the earth's heat was the energy of the nebula, though this has probably been reinforced by the heat produced by radio-active substances.

When we come to consider the earth's age, we derive many hints from its heat.

The heat which would melt a shell of ice covering the surface of the earth

The earth is still hot, but — if we neglect for the moment the matter of radio-active substances — it is cooler than it used to be, and by estimating its rate of cooling and the degree to which it has now cooled it is possible to get some idea of its age.

As rock and air are both bad conductors, the rate of cooling is comparatively slow, but still cooling goes steadily on; and Professor J. D. Everett estimates that the



HOW WE KNOW THE EARTH IS HARDER THAN STEEL

These lines represent vibrations through the earth and through steel. A tremor passes through the earth the distance of the bottom line in the same time as a tremor passes through steel the shorter distance at the top. As vibrations move more quickly in rigid bodies, this proves that the earth is more rigid than steel.

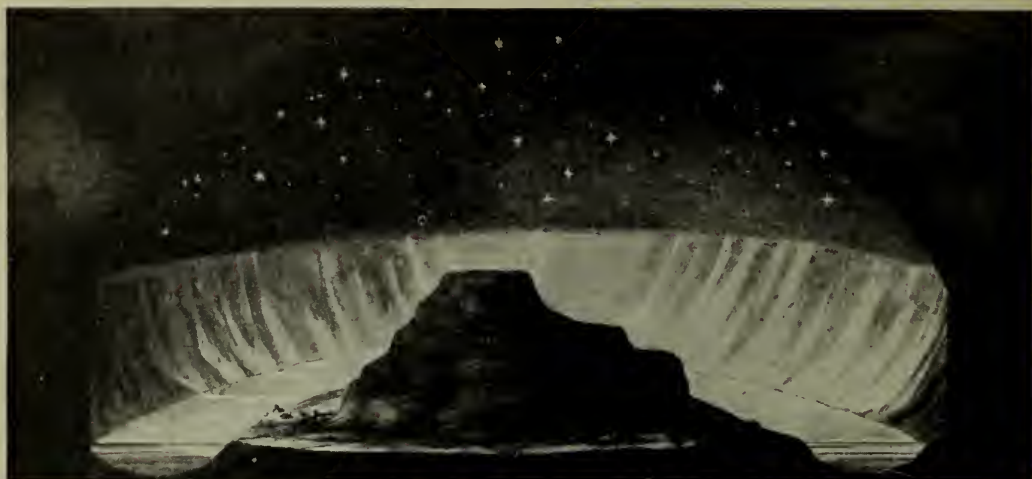
amount of heat leaking away from the earth every year would suffice to melt a shell of ice an inch thick over the whole surface of the globe. Of course, at varying epochs vari-

ous circumstances, such as ice on the land and carbonic acid in the air, must have affected the radiation of heat, but still it must have leaked away century after century, and it is possible to calculate in a general way the rate of leakage.

The original heat-energy of the nebula we cannot guess, but as consolidation of the earth's crust probably took place at a temperature of about 2000 degrees Fahrenheit, it is possible roughly to estimate the time that must have elapsed since then. From a calculation of this kind, Lord Kelvin came to the conclusion that the crust of the earth can be only twenty to forty million years old, and more likely twenty than forty, and he corroborated his figures by an estimate of the age of the sun.

The earth is certainly not older than the sun; and the sun cannot have gone on blazing as it does for more than a certain number of years; it, too, must be cooling.

WHAT THE EARTH WAS THOUGHT TO BE



Long ago, in the early ages of the world, the minds of men reached out into strange places in searching for an explanation of the earth. The Hindus thought the earth was borne by huge

WHAT WE KNOW THE EARTH TO BE



elephants standing on a gigantic tortoise swimming in a sea of milk; the Chaldeans thought it was an enclosed chamber surrounded by water; and even the wise Greeks thought it a disc floating in a sea.

The time it would take to freeze a white-hot globe as big as the sun

A globe of white-hot iron as large as the sun would cool to freezing-point in 48 years; a globe of coal as large as the sun would be burnt out in less than 3000 years; the rain of meteorites which is supposed to stoke the sun cannot have much fuel value, and until Helmholtz suggested that contraction was the main source of its heat the sun could be given only a short life. Helmholtz gave the sun longer life by proving that an annual contraction of sixteen inches would suffice to produce the solar heat. But even if we admit contraction, and suppose that the sun has contracted from an infinite nebula, we cannot give more than four or five hundred million years' life to the sun; and Lord Kelvin concludes that it is, "on the whole, most probable that the sun has not illuminated the earth for one hundred million years, and almost certain that he has not done so for five hundred million." Professor Tait is more niggardly still, and will not admit that the earth has had more than twenty million years of sunlight.

Estimates varying from twenty million to five hundred million years are obviously rough, and other plans have been taken to get more exact figures of the earth's age. Certain inferences have been drawn from the tidal retardation of the earth. We know that formerly the earth revolved more rapidly, and it is estimated that a thousand million years ago it must have revolved twice as fast, provided the rate of change has been uniform during that period of time.

Has the earth been spinning for a hundred million years?

Now, if the earth had consolidated when spinning at such a rate, it would have been flatter at the poles and more bulging at the equator than is the case. So, from a consideration of the amount of flattening and bulging, we can estimate the rate of its spinning at the time of consolidation, and from this rate we can fix the date of its consolidation. Working on these lines, most mathematicians fix the date at not

more than a hundred million years ago. But this reasoning is not quite sound, since, even if the earth had been more flattened at the time of its consolidation, it would not have been quite rigid at first, and might afterwards have altered its shape to suit the diminishing rate of its revolution.

The age of the earth has also been calculated on geological grounds, by estimating the probable time required for geological processes, such as the accumulation of the sediments produced by rain and streams. We can discover the rate at which land is worn away at present; and as we find great layers of so-called "sedimentary" rock made from wear-and-tear deposits, and as we know the thickness of the layers we can estimate the length of time the deposition has required.

The total thickness of the sedimentary deposits is about fifty miles. That is a tremendous heap of sediment, more than fifty times the height of Vesuvius, and about ten times the depth of the deepest sea. Now, it has been estimated that sediment is deposited on the average at the rate of a foot a century, and on such an estimate the earth would be about twenty-six million years old.

How long have the rivers carried salt into the sea?

But there are many difficulties in the way of getting reliable results from this method. We find that sediment deposits at very different rates, and that it is difficult, also, to estimate the thickness of layers of sediment. It is also known that many layers of sediment have been washed away by the action of the elements. Accordingly, by this method different geologists have attained very different results, varying from twenty million to a hundred million.

An interesting attempt has been made to estimate the earth's age by calculating the amount of salt in the sea. The sea, having been formed by condensation, was originally pure distilled water. Now the sea contains 144 billion tons of salt — enough salt to cover the whole dry land to the depth of 400 feet. The question is just



HOW LONG HAS THE SUN BEEN SHINING?

Lord Kelvin thought it probable that the sun had not illumined the earth for a hundred million years, and Professor Tait thinks the earth has had not more than twenty million years of sunlight. Other estimates give the sun a past of five hundred million years.

how long the salt took to collect. Every year the rivers discharge into the ocean 6524 cubic miles of water; and Professor Joly's analysis of the water of nineteen great rivers, discharging 488 cubic miles of water, showed an average of 5.73 salt per million. That means that the rivers discharge about 160 million tons of salt into the sea every year, and at that rate it would require 90 million years to accumulate all the salt now in the sea, and we might set that down as the age of the earth.

The data, however, is clearly not quite certain. By making a similar calculation of the total amount of sediment running into the sea annually, as compared with the total thickness of the sedimentary rocks, the geological age has been computed as some 80 million years. We find, accordingly, that geological and mathematical methods have succeeded in calculating the age of the earth only very roughly, and that results varying between 20 million and 140 million years have been obtained.

One must not, however, gather from the use of the words "mathematical," "calculate," "compute," etc., that even approximate values have been determined for the time elapsed since our earth became solid. All the so-called "estimates" are not much better than wild guesses.

How radium and its emanations affect guesses regarding the age of the earth

Of late the discovery of radio-active substances, such as uranium and radium, has cast new light on the problem, and has rendered it possible to add millions to the possible years of the earth. Radio-active substances are substances which contain atoms in the act of breaking up, and this breaking up of atoms generates heat. Now, the earth's crust has been found to contain radio-active substances in such quantities that even if they extend only ninety miles down they would suffice to supply all the heat that leaks away from the surface of the earth. It has been found, too, that great heat and great pressure do not affect radio-activity, and that radio-active substances continue to produce heat even at high temperatures. Radium is almost certainly present in the sun as well as in the earth; and it has been calculated that about $3\frac{1}{2}$ grams in each cubic yard of the sun would be enough to supply its heat for thousands of years.

This wonderful discovery of self-heating substances evidently affects all calculations of the earth's age from the facts previously considered, for if one source of the earth's heat be the heat now produced by radio-active substances, and if there be more than enough heat produced in this way to compensate for leakage, the whole problem is widened, and the earth has probably lived for many more years than the calculations of the mathematicians gave it.

The fiery furnace of the earth that may be creeping up to the surface

Not only does it become impossible to estimate the earth's age from the present temperature of its crust, but it is even quite possible that the earth is no longer cooling down at all. Though it may have been losing its heat, yet if there be radio-

active substances in the earth's crust and core, then heat is probably accumulating in the deeper layers of the earth, and may ultimately reach its surface and reheat it.

It may be asked why the heat in the center of the earth does not reach the surface at once; but if we consider the distance the heat has to penetrate with the fact that rock is a bad conductor, the reason is plain. Lord Kelvin showed that if the rocks in the earth's interior were as bad conductors as the surface rocks, the earth's core would retain almost all its original heat for a thousand million years; and in the same way the central layers may grow intensely hot, while the surface remains cool, and even grows cooler.

Altogether, the results obtained from these new calculations have led to a belief that the earth is much older than the twenty or forty million years allowed by Lord Kelvin. But we cannot say that the age of the earth has been definitely decided, and we must take the figures with a good deal of caution.

What the discovery of radium has taught us in regard to heat

What amount of heat is being generated by radio-activity in the center of the earth we do not know, but it is not improbable that heat is accumulating in the core, and that in a hundred million years or so the earth may be again a molten mass.

Radium suggests a new source of heat for both sun and earth; it allows us to suggest a much longer past for both, and a much hotter future; and it also suggests that there is a smoldering fire in the heart of the world which will eventually consume it. According to this new view of things, if radio-activity exceeds a certain point the earth will become a furnace; and if it fails the earth will gradually become ice-cold, with liquid air lying on the frozen seas. It is strange to think that this mighty globe should be at the mercy of a few decaying atoms, but so, in the light of our new knowledge, it would seem to be. What an instance of the power of the infinitely little over the infinitely great — "the unending flow of energy from unstable atoms wrecking the stability of a world"!

WHAT WAS THE ORIGIN OF LIFE ?

The Power Which in Its Very Simplest
Form Passes Human Understanding

WHAT THE EYE OF FAITH MAY HOPE TO SEE

HAVING surveyed the variety and power and majesty of life, we naturally ask : Where does it come from ? A simple, straightforward query, but at present so unanswerable that very few men of science are even trying to answer it. But though no scientist can say where life comes from, and though no one can create even the simplest living thing, we do know a great deal which may help to answer the question some day.

Let us define our problem. Here are all manner of living things upon the earth, animal and vegetable, high and low, mammoth and microbe. One and all they are destined to die. But though all individuals are mortal, life itself is maintained by reproduction or parenthood. The living things we know, whose production of the next generation we witness in flower and fruit, in kittens and lambs and foals, are themselves the offspring of parents like themselves.

That is one stage of our inquiry. All the living things now upon the earth of which we have any knowledge are the offspring of others like themselves. The origin of the existing life on the planet to-day is therefore to be found simply in the parents of present individuals.

But the question arises : Are we right in assuming that this is wholly true ? Though we are sure that existing children have all had living human parents, are we sure that all existing microbes have had microbic parents ? Is it not possible that some of them have arisen by what is called "spontaneous generation" from dirt and water and air and other such materials ? We may safely assume previous

cats, sheep, human beings, wherever we observe kittens, lambs, babies ; but, though we are sure in these cases, can we be so sure in the case of microbes, or the amœba of the ponds, or other forms of life which are so small and simple, and seem so easily to make their appearance "from nowhere" ? Is it not possible that some of these do represent a fresh beginning of life from the lifeless ?

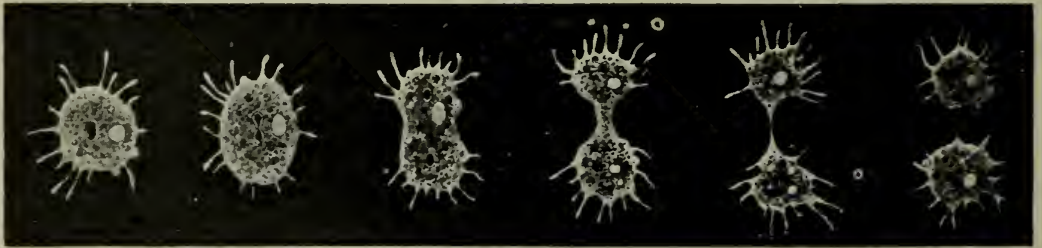
But the critic may reply in response to such questions that he is not really interested in the origin of microbes and amœbæ, which are so insignificant and undistinguished. He wants to know where the great forms of life, noble trees and nobler men, come from ; and if he is assured that they always come from ancestors like themselves, he wants to know where the *first* trees and men came from.

If we ask the origin of all or any of the living species which we see around us, and of which our own species is one, we plainly have to choose between two possibilities. Either they each began independently, somehow, as we see them now, or else they have originated from common ancestors, and by a process of evolution developed and diverged from one another. The doctrine of their independent origin, according to which all the forms of animals and plants were created once and for all, as they are now, and have been maintained to the present day by the process of parenthood, "like begetting like," is known as the doctrine of "special creation."

Opposed to this theory of "special creation" is the theory of evolution, which relatively few people really understand. It does not, as all too many people think,

do away with the idea of a Supreme Being nor does it deny that the universe of living things is the work of the Creator. This theory has nothing whatever to say concerning the *origin* of life. It accepts the existence of living things, both plants and animals, as a fact and seeks to find the laws and their modes of operation whereby living things in their long history and development on earth have changed in form and structure from what they were ages ago to what we find them to be today. In the words of Dr. J. M. Coulter: "It should be kept in mind that the problem is to explain how one species can produce another. The study of organic evolution deals only with the succession of forms, with the production of new forms by previously existing ones. It has nothing to say concerning origins. How the numerous

one who understands the principles underlying organic evolution would dream of trying to find the origin of trees or birds except in other forms of life which came before them; and if we continue this line of thought long enough, we come, by necessity, to the humblest and most primitive forms of life that we can discover. When we have reached these most primitive living things, and cannot trace their origin to anything humbler, as we can trace birds to reptiles, we are at a standstill. In fact, we have reached the real problem of the origin of life. If we could explain the origin of these humblest things we should have evidence which would permit us to believe that higher forms of life would follow; therefore the origin of the lowest form of life is the whole problem.



THE ASTOUNDING POWERS OF REPRODUCTION OF THE AMOEBA, THE SIMPLEST CREATURE KNOWN

This series of pictures shows an amoeba, one of the simplest animals that we know, reproducing itself as we watch it through the microscope. In the second picture the single nucleus is forming into two; in the third it has definitely become two, and the amoeba is elongating itself; in the fourth and fifth the body is splitting in two; and at last, as a result of the division, two amoeba are in the world.

series of living forms may have originated is certainly beyond the reach of biological science as yet. When one goes beyond the observed changes, and tries to trace the successions back to their source, he is in a region of speculation, and outside the boundaries of science." If, therefore, the reader will kindly bear in mind as he pursues the remainder of this chapter that we are endeavoring to set forth the views and contentions of those who still are seeking a solution of the origin of life, to set forth the facts and the interpretations on which they base their contentions and speculations, he will be in a position to judge for himself the validity of the views presented. Careful study shows that the various kinds of animals and plants have somehow evolved from one another, higher forms being developed from simpler ones, and those from simpler still. No

Thus, when men now study and discuss the origin of life it is understood that they are studying the very humblest possible forms of life, and that if they could prove the "spontaneous generation" of the tiniest, rudest, feeblest, living speck from materials in which there had formerly been no life as we understand it, all later developments of the powers of life would have found their key. The question therefore is: Do any living forms, however humble, take their origin from lifeless matter?

The keenest and bitterest controversy raged over this question a generation ago. The verdict at the time was that lifeless matter never produces life, and therefore that some entirely special and unique cause must have endowed our planet with its first life. The students of the earth report with absolute certainty, on over-

THE RUINS OF ANOTHER WORLD



Perhaps the most imaginative theory ever held of the origin of life on the earth was that of Lord Kelvin, who suggested that possibly the first germs of life might have been borne to earth "on the moss-grown ruins of another world," meaning such a planetary fragment as this. The suggestion has in it more imagination than science, but it is significant that it should have come from such a man as Lord Kelvin.

whelming evidence, that it was once in such a state of heat, to mention nothing else, that no life could have existed upon it. It is now covered with life; and yet, so far as men have been able to discover, non-living matter does not give rise to living things.

Many who took part in that controversy maintained not only that living things do not arise from lifeless matter, but that they never did do so in the past. Among those who held this view, two theories as to the origin of living things on earth arose. Of these, one was the theory of "special creation" in a slightly different shape, asserting that, though the different forms of living beings were evolved from one another and from simpler forms, the first germs of life were specially created and planted upon the earth, by the special interposition of the Creator. This theory prevails today and many of the strongest adherents of the doctrine of evolution concede that no better theory has yet been advanced.

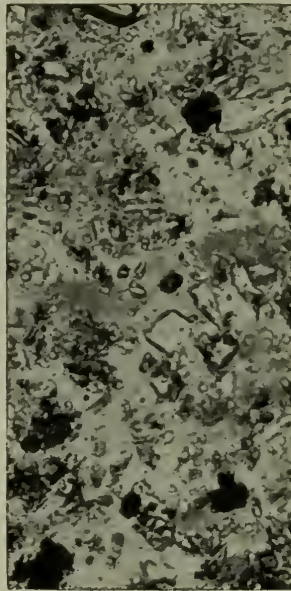
The alternative theory was a very ingenious and sensational one. It suggested—Lord Kelvin being the leader of this school of theorists—that possibly the first germs of life might have been borne to our earth "on the moss-grown ruins of another world."

Some older planet, comparable to Mars or Saturn, might have had life upon it, and in the course of its travels might have undergone a collision with another celestial body, and its "moss-grown" fragments might have formed meteorites, which might have later encountered the earth, been attracted by its gravitation, and thus planted "moss" upon its surface.

One can only dimly imagine what the leaders of science would have said if such a theory had been put forward by some distinguished clergyman or architect or lawyer. The time has long passed when there is any need to discuss its details in

a serious fashion; but it is of too great interest as a feat of the imagination and as part of the history of science to be wholly omitted here. The only comment which requires to be made upon it is that, even assuming all the incredible things which the theory requires, it merely alters the site of the problem, and we must ask just the same questions as before, except that we ask them of "another world," and not of our own.

Pasteur showed, by a long and magnificent series of experiments, that if tubes or vessels containing the forms of life which he called "microbes," or yeast-cells, or any



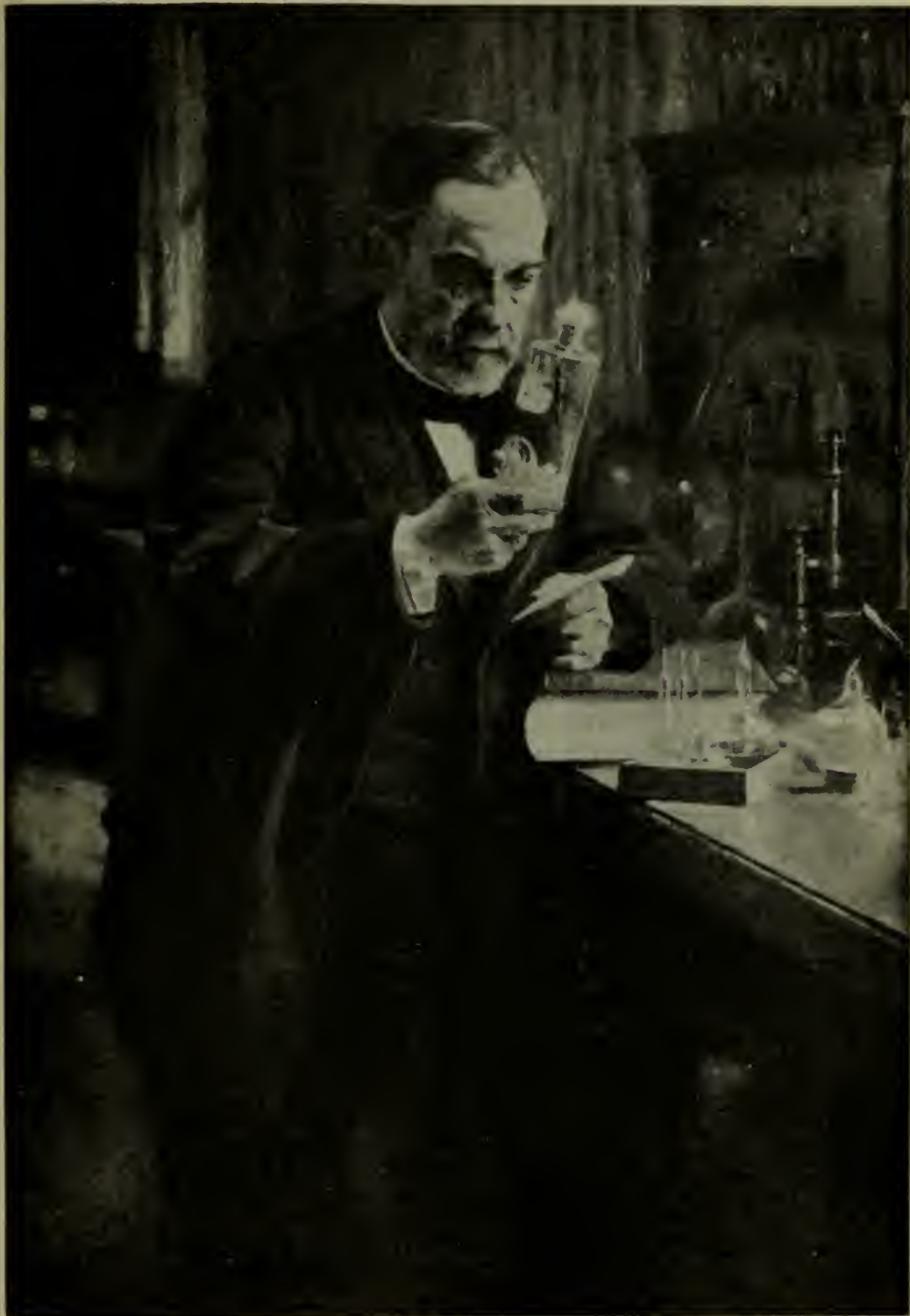
SAND GRAINS, SHOWING THE
STRUCTURE OF NOT-LIVING
THINGS

other of the humbler forms of life, be boiled or treated with a less degree of heat for a considerable time—a process now called "pasteurization"—no life subsequently appears in them. They are "sterilized," as we call it. After the treatment which has destroyed all existing life, the test tubes or vessels may be plugged with cotton-wool, which freely admits the air; but though all necessary materials, as we might suppose, are present for the formation of new living beings, and though the air has ready access to them, no life appears. These results, which have been confirmed incessantly since that time, were in utter opposition to the

generally received belief. They completely upset the current views as to the origin of microbes and other agents which produce disease, and of course they are daily matters of life and death to mankind in their bearing upon the control of infection, the use of disinfectants and antiseptics, the preservation of milk and other food, and in many lesser ways.

But instead of keeping simply to the facts which Pasteur had proved, men drew from them conclusions, which are still generally accepted, but which these facts, remarkable as they are, in reality do not in the least justify.

PASTEUR AND THE WORLD'S GREAT RIDDLE



The possibility of the production of life from not-living things was keenly debated by the scientists of the last generation, and Pasteur made up his mind against this possibility after a long series of experiments, which showed that, with all the known materials ready in the test-tubes, no life could be produced.

This photograph is the copyright of Messrs. Braun, Clement & Co.

Trying to prove a universal negative on insufficient data

Because no recognizable life appeared in certain boiled or long-heated solutions and mixtures, men assumed it proved that no forms of life, known or unknown, ever appear in any part of the world, ocean depths, or hillside soil, in any circumstances except from preceding life; and many men went on to declare that the experiments proved that life not only did not arise from lifeless matter, but could not, either in the present or in the past.

It is the most difficult thing in the world to prove what is called a "universal negative," but here men thought to prove a universal negative as to the origin of life, on the strength of experiments which could not by any means include one in millions of the possible varieties of circumstances.

Nothing is gained by claiming more for the results of experiments than the facts so obtained actually warrant. Pasteur by his experiments and his followers, by repeating these experiments daily since his time, have shown as conclusively as it is possible to show under the circumstances that living things do not arise from non-living matter. But with due appreciation of the results thus obtained we must still recognize the fact that they do not prove that it is impossible. We know that there was a time when living things were not present upon earth and we know also that the constituents of living bodies today do not differ from the elements found in lifeless matter so that at some time in the past lifeless matter was endowed with the powers of life. Now, if we try to compare present conditions with any that we can imagine to have obtained in the past, we find that all the advantage, for the purposes of life, is with the present. The earth is now crammed with life; the conditions for the maintenance of life can never have been better: why not, then, the conditions for making it? All the required chemical elements are available, there is plenty of water, and of oxygen to breathe, and all the possible temperatures at which life can exist at all are available. Above all, there is a

vast quantity of ready prepared food material, and of complicated chemical compounds, such as living bodies need and are made of, which have been made by the present life of the earth. Yet we are forced to admit that, so far as we can discover by investigation or by experiment, no life ever arises anew on our planet now even in the presence of all those conditions that seem to us most favorable for its origin. But that life did arise long ago when not a single one of the food materials which life relies on was available remains a fact. This is the difficulty we find ourselves in, and there is only one way out.

The marvelous complexity of the simplest forms of life we know

We must give up the idea, for which we have no warrant, that the lowest forms of life we know are really the lowest and simplest that can be. The students of mankind, for instance, are only just beginning to realize that the lowest known forms of men are far above primitive man. Just so the students of life are now beginning to realize that the lowest known forms of life are in all probability far above what primitive forms must have been. The amoeba is the simplest form of animal life that we know, and we assume it to be the simplest that can be. Yet it has a complicated structure—much too complicated for us to have unraveled yet; and it possesses varied and delicate powers of locomotion, sensation, digestion, excretion, and reproduction, which have only to be thought of for anyone to realize that vastly simpler forms of life are imaginable.

Really it is amazing how we can ever have supposed that the amoeba, or even the simplest of the green plants, is really primitive; and it is scarcely less amazing that notable students have been able to believe that such marvelously skilful and complicated beings could arise in a few hours out of a mixture of chemical compounds and air and water.

It is as incredible as the view of the last generation that the civilization and culture of Athens were built in a few decades out of barbarism, a view which we know to be as false as can be.

The long stages of evolution of which we can find no trace

It is very probable that the simplest living thing we know represents the result of a long period of evolution, with many remarkable stages, all trace of which is now lost; and that the experimenters who deny the possibility of "spontaneous generation" on the evidence of a few days or weeks might as well expect the plays of Shakespeare to be written without the invention of an alphabet and without a word or two being necessary. If we are to possess ourselves of the only belief which satisfies the reason, and are to travel along the only road which will lead us to definite discovery, we must give up the idea of the *amœba* as primitive, and must ask what a really primitive living being would be.

All the living things we know now consist of cells, and cells are wonderfully complicated structures. It is reasonable to suppose that the simplest cell may have taken thousands or millions of years for its development into the complex structure we now find it. The modern study of the earth's crust gives us as much time for evolution to work in as anyone can ask for, or any theory require; and we who now have begun to realize what a marvelous thing the simplest unicellular animal or plant is may well believe that many ages were required for its evolution. Long before the living cell appeared, thereafter to become the unit of all living things without exception, we may suppose that there was living matter, or protoplasm, as Huxley called it, "the physical basis of life." And now, basing our reasoning on what we know of animal and plant life today, what kind of living matter could we expect to first appear on the earth?

The plant life that prepared the way for higher forms

It would be in no sense an animal, nor yet like an animal in its habits. For animals, without exception, require for their food material which has been already prepared by the action of living things. Plainly, therefore, nothing of the nature

of an animal, as we understand animal life today, could be the first living thing.

If we turn to the plant world, we find that microbes appear to be the simplest of its forms of life. But microbes are like animals, in that they can live only upon material which is itself alive, or which has been made by living things. Though they are plants they are regarded as degraded, unplantlike plants, and are as dependent on other forms of life as animals are.

Thus we have ruled out both the simplest of known animals and the simplest of known plants.

The first forms of life must necessarily have been plantlike in this fundamental respect, that they could live upon materials not made by any preëxisting life. At some later stage the first animal forms must have been produced, able to live because their plant predecessors and contemporaries provided them with nourishment — as plants everywhere maintain animal life now.

Can this marvelous universe have arisen from dead matter?

Life depends upon chemical changes; and if all chemical change ceases, life ceases. "To live is to change," as Cardinal Newman said. And the words are literally true of every part and aspect of all life, bodily and mental. The only manner in which chemical change can occur for the purposes of life is in a fluid most of which is water, which is the great solvent of other substances, and the great medium for their interaction. And since it is true today that the protoplasm of cells in which the functions of life are manifested is largely water, it is assumed that these first forms of life appeared in the waters of that day.

As for the date at which these first forms made their appearance, we must refer to geology and physics. Geology has some kind of record, and may make guesses as to the age of the rocks in which remains of life first appear. Physics may reckon how long the earth has taken to cool. Other sciences contribute, as when chemistry studies the salt contained in rivers, and thence tries to measure the years during

which the rivers must have been pouring salt into the sea in order to make it as salt as it is at present.

These estimates vary at present, and ever increase in length, as we gradually begin to learn the part which radium, and the powers of such substances as radium, have played in the formation of the earth's crust and seas. But it seems reasonable to believe that life must have existed for not less, at any rate, than hundreds of millions of years.

So much for the probable character and the probable date of the origin of the first of living things. We have to ask again, in the light of our new knowledge, whether it can be believed that this marvelous thing, with its almost infinite powers and its conquest of the earth can possibly have arisen from what we call "dead matter." Here, as in so many other cases, the discovery of radium and its properties helps us beyond measure.

The atom that seems to be intermediate between the living and not-living

If we do indeed think of the not-living world as being composed of "dead matter," in the sense that its atoms have no force or properties of their own, but are simply acted upon from outside, then it seems a simply unimaginable thing that such a marvel of spontaneous and original activity as life could have arisen in such unpromising material. We should find it easier to believe that life entered the world from somewhere else, or from nowhere, and possessed these atoms until they became alive. But the case is very different when, instead of our old ideas about "dead matter," and instead of looking upon atoms as forceless in themselves and merely the sport of forces outside them, we come to remember what very lively things atoms really are.

Thus we come to the second of two ways in which modern thought and knowledge are seeking to bridge the apparently impassable abyss between the living and the not-living. We are endeavoring to accomplish it by advance in both directions—from the living to the lifeless, and from the lifeless to the living.

The mysterious force that works in atoms stored with marvelous energy

The gap between the amœba and "dead matter" is hopeless, but it is not real. The domain of life stretches far across the gap in living forms which, perhaps, have mostly disappeared from the world of to-day, but may yet exist, and may even now be in process of evolution from the supposed lifeless. We do well to remind ourselves of what the students of disease now say—that the belief now prevails that there are living causes of disease which are so much smaller than ordinary microbes that they cannot be seen by any microscope, if indeed they can be stopped by any filter.

And now the new chemistry throws out strong girders across the gap from the side of the not-living. It shows us that "dead atoms" are very far from inert in themselves, though they may be dead when compared with the forms of life we know. It shows us radium and other elements composed of atoms which are crammed with incalculable stores of energy, and are most certainly doing things at every moment of what we can scarcely help calling their lives. These new facts are none the less significant if we remember that certain atoms can act as ferments, causing active and potent chemical changes.

"Organic chemistry" and "inorganic chemistry" are really one

Constructive chemistry goes farther still. It builds up, from simple atoms, such compounds as alcohol, sugar, and even the simpler forms of the proteins, which are usually made by living beings alone, and which men supposed, not long ago, could be made only by the processes of living bodies.

We still talk, indeed, of "organic chemistry" and "inorganic chemistry," of which the first deals with the chemistry and the compounds produced by living organisms, and the second with other compounds. But every chemist knows that the two chemistries are one, and that the gap between organic and inorganic does not really exist.

The strange processes which may hold the key to all our questionings

Not only does chemistry construct so-called "vital products" artificially in the laboratory, but it directs our attention to a group of compounds, called "ferments," which may hold the key to many of our questions. Clever experimenters suppose that they have produced living beings by the action of radium on bouillon; and others endeavor to galvanize special mixtures into the form or semblance of life. These attempts all prove disappointing. But the chemistry of the ferments makes steady progress. Some ferments can be made artificially — an achievement which perhaps approaches nearer than anything else to the performance of the functions of life. For ferments can produce and keep going chemical changes of the most wonderful kind, without themselves undergoing change or exhaustion. It is probably the literal truth that life, considered from the physical and chemical point of view, is a series of fermentations. All living things contain ferments, and cease to live if those ferments cease to be able to work. Great features of adult individuals are now said to be due to the presence, or absence, or particular combination, of certain ferments in the germ-cells from which those individuals developed. The science of ferments has done more than all other branches of study put together to bridge the gap between the not-living and the living; and we must remember that the study is in its infancy.

A new branch of science has been formed to deal with this subject. It is called "biochemistry"; that is to say, life-chemistry. In its development are now hidden, and may ere long be revealed, the nature of fermentation, many of the mysteries of heredity and development, and most of all of the hitherto unsolved mysteries of disease, especially those concerned with abnormal forms of living action, such as the growth and behavior of cancer-cells. Meanwhile, we may be satisfied by the first fruits of research already before us, which lead men to hope that the gap between the not-living and the living may

not be without a bridge and that all stages from the single unlinked atom, or even from the electron, up to the living organism, may yet be demonstrated by those who come after us.

Life, however, will be none the less real, none the less different and characteristic and wonderful, because we are able to trace its history and its connections, unless, indeed, we are always to discount or decry great things, great art, or great men, or great ideas, on the ground that we can trace "the base degrees by which they did ascend." If it be true, as many men in modern science believe, that the possi-



PROFESSOR JOHN TYNDALL

bilities of life are latent in the universe, that, as Tyndall declared, the eye of scientific faith can see in the fire-mist from which our earth was made all "the promise and potency of terrestrial life" — the worm and the bird and the oak, and Shakespeare and Plato — then the only conclusion we can draw is not that Shakespeare is therefore less Shakespeare but, that "dead matter" and "mere, gross, material things," and "the blind forces of the mechanical world" are less gross and blind than we suppose, since they are the servants and do the will of the living power that moves through all things.

A NATURE METHOD OF SOIL FORMATION



From Whitson and Walster's *Soils and Soil Fertility*, Webb Publishing Co.

STREAM AND ITS ALLUVIAL SOIL

Portions of the sediment carried oceanward by rivers are from time to time deposited as fertile strips of soil along the parent stream.

HOW THE SOIL WAS FORMED

The Making of the Thin Coating of
the Earth upon Which all Life Depends

THE GRINDING OF THE ROCKS TO POWDER

WITH a proper idea of the composition of the soil and its relation to plants in mind, the next question to be considered is exactly how the soil came into being. If it is a debris of rock mixed with organic matter, how came it in this condition? Why is a soil the natural covering of the earth's surface? What power has brought about this change and what forces have been utilized?

As might be expected, the question is a complicated one, as the rocks are so variable in their composition and the forces at work so many. The process of soil formation in general may be defined as *weathering*, since the forces at work are very largely atmospheric. Water, heat and cold, ice, wind, plants and animals, and oxygen all have had a part in the reduction of rocks to soil. Common everyday forces dealing with this common everyday soil! They have had a hand, too, in the addition of organic matter and in the mixing of this decaying material with the rock particles in a way that nature alone can provide.

Everything on the earth's surface is changing. The exposed rock everywhere is being slowly evolved toward soil. The soil is not stable. It too is changing, possibly to a better or possibly to a worse condition for plant production. It is a part of our geologic kingdom. It is never still. It is continually subject to the stresses and the strains that brought it into being from the parent rock. These same forces continue to act and to act vigorously after the soil is formed. It is well that this should be so, as the hard treatment which the soil has received and is still receiving at the hands of the weath-

ering agencies has made it and continues to make it useful to plant life. The fertility of the soil, then, is closely related to its mode of origin.

The addition of organic matter begins early in the history of soil formation. A little dust is blown among the rock fragments. It is moistened with rain. Simple lichens and mosses grow. They die and are succeeded by others. Higher plants wrest a foothold, obtaining food from the rock, the air, and the accumulations of former plants. Tribe after tribe springs up, reigns, and dies, drawing sustenance both from air and soil. The rock particles become finer and finer, organic matter accumulates, and a vigorous teeming population of bacteria seems to spring from nowhere. Thus a soil is born, not instantly, but over geologic ages and through the travail of natural forces. This is the origin of the medium which furnishes us with bread. May we not look with interest into a few of the details of this history of strife, struggle, and success?

The force of water

From the time the raindrops beat down upon the earth until they are discharged into the ocean as mighty rivers they are engaged in wearing away the surface and conveying the debris seaward. They not only carry but they erode. The granules loosened by the frost are caught in the rivulets and are swept into the streams and rivers to be perhaps later spread out as a valley soil when the stream becomes sluggish. The gorges, the canyons, the river channels, and the valleys everywhere are evidences of water work. The pound-

ing of the waves on the seashore is but another example. This continual wearing away of the land is a constant reminder of the power of water and the part it plays in nature's method of soil formation.

Heat and cold

Water acts in another way in the grinding of rocks, a way which is more effec-

water it contains. The force exerted is terrific, being equivalent to the pressure of 150 tons per square foot. The rock is cracked by this force not in one direction but in many and not one time but many, many times through the ages, until its fragments become so small as to form, when plant remains are added, that intimate mixture of mineral and organic matter that we call the soil.



From S. W. Fletcher's *Soils*, Doubleday, Page & Co.

TAUGHANNOCK FALLS, N. Y.

From the time the raindrops beat down upon the earth until they are discharged into the ocean they are wearing away the rocks and conveying the debris seaward. Our beautiful landscapes are largely the result of such action.

tive than any means devised by man. In this it is aided by heat and cold. When a rock is warmed by the sun it expands but it does not expand equally. It is a mineral aggregate, and the minerals do not swell or contract exactly the same with change in temperature. Consequently, little rifts appear between the separate minerals into which water can creep. This is not all the damage done, by any means, for the water may freeze and expand. You have seen how easily a pitcher is broken by the freezing of the

The grinding power of ice

Ice may affect rock masses in still another way. We all know of the glaciers that today exist in Alaska and Greenland. They are great rivers of ice formed from the accumulation and compacting of snow, which push down from the higher altitudes, carrying all before them. As they slowly advance, pushed forward by the pressure above faster than their fronts melt back, they grind and crush and scrape the rocks beneath until a great mass of

powder and detritus is formed. Part of this is carried away by the water from the wasting ice while part is laid down as a mantle over the scarred earth when the ice melts away.

Many thousands of years ago, probably before the development of man, the whole northern third of the United States as well as all of Canada was several times invaded by a great continental sheet of ice which pushed forward and melted back many times. This sheet of ice was not only miles in extent but many feet thick. Its grinding power was terrific. When at last the retreat into the arctic regions came, the face of the earth was left covered everywhere with ice-ground powder. In places it was thick and hummocky but usually it lay as a smooth mantle. Plants obtained a foothold, organic matter accumulated, and today we see these soils rich and productive, dotted with the homes of countless thousands of happy people.

The action of the wind

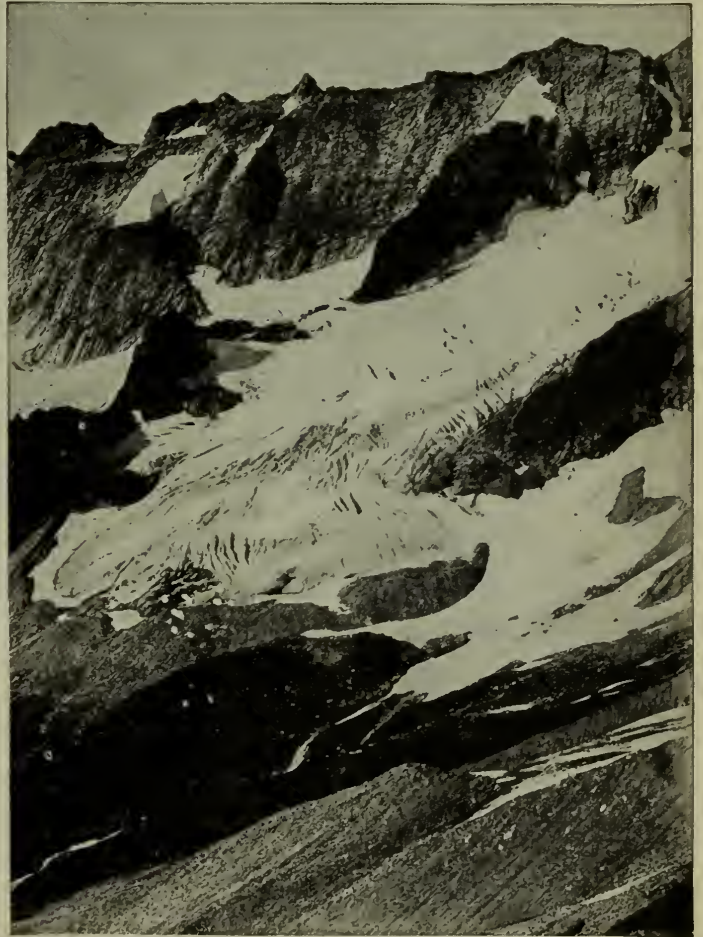
We do not usually consider the wind as a soil-forming agent; in fact, it often seems to act in just the opposite capacity. However, it does really help to break down rock and produce soils. Like water it has two phases of action: in wearing away rocks and in transporting finely ground material. As an eroding agent it has little practical importance unless it is



From Merrill's *Rocks, Rock Weathering and Soils*, © The Macmillan Co.

DIORITE BOULDER SPLIT BY FROST

Change of temperature, especially when ice is formed, exerts a force so mighty as to split the solid rocks into fragments. These fragments may produce a fertile soil if a sufficient amount of organic matter is present.



From R. D. Salisbury's *The Glacial Geology of New Jersey* (photo by Willis)

GLACIERS IN CASCADE MOUNTAINS

Sheets of ice, called glaciers, crush and grind and scrape as they invade lower and warmer lands thus furnishing the debris which may later be changed by weathering into soil. Much of the arable land in northern United States and Canada was produced in this way long before man was of importance on the earth.

armed, that is, unless it carries fine particles of sand or grit which actually do the cutting, the wind supplying the force. The grooving of rocks in dry regions and the scratching of window-panes near the seashore are evidences of the cutting power of the air when in motion.

It is as a transporting agency, however, that the wind most interests us. Over untold centuries the westerly winds in our Mississippi Valley have been engaged in carrying soil particles. These particles have accumulated in Iowa, Illinois, and neighboring states to such an extent that they are now of great agricultural importance. They cover the earth's surface sometimes as high bluffs, sometimes as low hills, but more often as beautiful rolling prairies. As the mineral elements under plentiful rainfall have been abundant and available, generation after generation of plants has grown on these so-called "loess" deposits.

Organic matter has accumulated and rich soils have been evolved. They contribute much to our national prosperity and welfare.

Plants and animals

To the disintegrating action of water, wind, and ice is added the supplementary influence exerted by plants and animals. Unlike the agencies previously discussed, plants and animals succeed rather than initiate rock decay. Simple plants, such as lichens, will readily develop on coarse rock fragments. They catch dust and provide organic matter for later and higher plants that send their rootlets prying and creeping everywhere to loosen the native rock. It is perhaps upon the partially formed soil that plants and their roots have the greatest effect. The soil is loosened and opened to the beneficial action of air and water. The intimate

mixture of mineral and organic matter is stimulated and promoted. Plant food is unlocked for succeeding crops and the soil becomes richer not only through addition but through change in constitution.

Animals also influence the fining of rock fragments and of soils by their burrowing tendencies. Squirrels and gophers open up and mix the soil. The mole, although not a favorite with farmers, has performed a work hardly to be neglected. Of all of nature's plowmen, however, the earthworm is by far the best. In some places almost all the top soil has passed through the bodies of the worms that year after year and century after century

have lived in the earth. Not only this, but the worms bring great quantities of earth to the surface, thus mixing and working the soil in a way not otherwise provided for by nature. Moreover, by boring down into the lower depths the worms provide

drainage for surplus water and for the entrance of the pure fresh air so necessary for plant roots. From these few illustrations we may form some idea of the work done towards the plowing, mixing, airing, and draining of the soil by the great army of rodents, worms, and insects which make the earth their refuge and home.

Chemical and physical weathering

The agencies already recognized as so important in soil formation have been discussed only as to their physical effects, that is, their splitting, breaking, grinding, and mixing actions. That food elements must be in solution in the soil water before they can be utilized by the plant makes it evident that there must be another side to soil formation. This is the chemical phase and is partly a function of oxygen



From Lyon's *Soils and Fertilizers*, The Macmillan Co.
Even such simple forms as lichens play a part in the breaking down of rocks and the formation of soil.

and partly an action of water. That it is a very complex change is apparent. The original rocks are so complex, the organic matter later added is so intricate, and the interactions between the two are so numerous and so difficult to understand that it is not worth our while here to inquire very far into the subject. It is enough to realize that soil formation is a geologic process and that it includes not only the fining and mixing of the mineral and organic debris but also complex chemical interactions which liberate plant food and stimulate bacterial action.

The function of oxygen

When a bright shiny plow or hoe is left out in the rain or dew it will in a short time be covered with rust. This rust represents the effect of the oxygen of the air and is simply a change in the composition of the implement due to chemical action. The oxygen unites with the iron or steel, forming another compound called in this case iron rust. Not only is the iron of the soil affected in this same way but other materials unite with the oxygen. Although the action is slow, it is effective, since the soil has so long been exposed to atmospheric influences.

With the oxygen we find another gas working, a gas formed from the union of

oxygen and carbon. It is called carbon dioxide. It supplements the work of the oxygen and produces compounds called carbonates. Limestone is a common example of a carbonate. Under the action of oxygen and its offspring, carbon dioxide, the rocks slowly decompose. The fining due to physical agencies presents a great surface for action. The rocks

become soft and discolored. They develop red and yellow colors. The splitting and grinding are encouraged and soil formation goes on at an increased rate. Had we not had the action of oxygen it is doubtful if there would now be any soil on this earth.

The effect of oxygen is vital in another way. Without its action food would never become soluble and consequently could not be used by higher plants. Oxygen thus

is continually renewing the fertility of our soils.

Solution and its importance

Water is present everywhere on the earth's surface, and its effects are numberless. We have already seen how it erodes and cuts, how it carries and deposits, how as ice it grinds and abrades, and how as it freezes it splits and breaks surrounding materials. In all of its soil-forming activities, however, its chemical effects are



From Lyon's *Soils and Fertilizers*, The Macmillan Co.

The roots of the forest trees often exert a prying force sufficient to crack and rend the solid country rock. The other forces of soil formation are thus aided and encouraged.



From Lyon's *Soils and Fertilizers*, The Macmillan Co.

The tangle of ramifying roots that keep the soil stirred and aerated mightily promote soil fertility by the organic matter that is constantly being added to meet the rapid losses due to the action of bacteria.

probably of greatest importance. It carries air and carbon dioxide into the rocks and soil and encourages the action of these gases. It is taken up by the rock and becomes chemically combined with the minerals, thus exerting a weakening influence. But, above all, it acts as a solvent for the simple materials that are developed by chemical reactions. It is in this latter capacity that water especially interests us here. It is now quite evident that the chemical manifestations of weathering ultimately result in the simplification

Solution is the sum-total of weathering, inasmuch as it is in this form that food is supplied to the plant. If the physical and chemical forces do not produce soluble material, no available plant food can be present. Solution must be continuous in the soil, since the soluble plant food at



from S. W. Fletcher's *Soils*, Doubleday, Page & Co.

The industrious ant moves and mixes many tons of earth each year and thereby unwittingly plays an important although unappreciated part in nature's scheme of soil formation and renewal.

any one time is small and must be constantly renewed. The importance of weathering, especially that of a chemical nature, hardly needs to be reemphasized, for evidently upon it lies the task of renewing and maintaining the fertility of our soils.

Practical importance of weathering

It must not be inferred that the various physical and chemical forces engaged in soil formation act separately or alternately. As a general thing their action is combined. Thus the one set of factors aids and accelerates the other. Again we must not lose

of compounds and that these compounds must go into solution before they can be used by the plant. In this action water is greatly aided by carbon dioxide, which not only comes from decomposing soil organic matter but is brought down by rain and snow. It makes the soil water slightly acid and increases its solvent power.

sight of the fact that the work of these agencies is not completed when the soil is formed. They must now maintain the fertility of their handiwork. The physical agencies loosen and fine the soil. The wetting and drying, freezing and thawing, burrowing of animals, blowing of winds, and running of water, tend to maintain a

condition favorable to root extension. The action of oxygen, of carbon dioxide, and of water bring the materials thus fined into solution until all the factors necessary for good plant growth are supplied. It is little wonder that the farmer by plowing, harrowing, and draining, and by adding organic matter and lime tries to encourage such benefactors and friends for he is at the mercy of nature and her forces.

The various kinds are as follows :

1. Formed in place — residual.
2. Transported by

{	water	{	river — alluvial
			ocean — marine
			lake — lacustrine
		{	ice — glacial
			wind — æolian



From Lyon's *Soils and Fertilizers*, The Macmillan Co.

Swiftly flowing water has great cutting and carrying power. It is thus provided with the sediment, which it later builds into soil along its lower reaches.

Kinds of soil

Weathering produces the soil wherever we find it, whether on the hills or in the valleys, on the mountains or in the lowlands. Usually one particular agency so predominates that we can name the soil therefrom. This gives us a means of classifying soils according to their origin and lays the foundation for a very simple and easy method of grouping that serves to distinguish soils wherever they may chance to occur.

Residual soil

The residual soils are formed in place by wearing, washing, and dissolving away processes. The part remaining behind is the soil, hence the name. Such soils are old soil, highly colored through the action of oxygen on the iron, and they contain but little soluble matter. They are soils of but medium productivity. They are found best developed in Virginia, North and South

Carolina, Georgia and Alabama. They cover probably one-fifth of the surface of the United States. The material carried away in the formation of residual soils must find a resting place somewhere. This is always at lower levels. As water is the transporting agency this debris must come to rest along rivers, in oceans, and in lakes. Thus we have the names "alluvial," "marine" and "lacustrine," for the soils formed in this way and are led logically to a consideration of soils laid down by water.

Water laid soils

If water is flowing swiftly it has great carrying power for fine materials, but any checking of its movement causes a deposition of the debris so carried. In the lower portion of a river the current generally becomes sluggish and the stream begins to swing from side to side, depositing sediments on either bank. The overflow of a stream carrying sediment, as it always does in flood, causes the deposition of thin layers of soil over the flooded areas. As a result, narrow ribbons of such soils are found along almost every stream. They are young soils, usually rich but likely to be poorly drained and subject to overflow. Along the Mississippi River great areas of such soil exist and constitute lands of no little agricultural value.

Not all the sediment finds lodgment along the streams. Some is carried to the mouth of the rivers and discharged into the body of water receiving the drainage. Here it settles down on the bottom, and if time enough elapses will form deep deposits. Such accumulations may take place in ocean or in lakes. These materials are not soil, however, unless they are raised above the waters and become dry land. Often through some great and gradual earth movement the sea recedes, leaving the sediments, or the lake through some geologic action may be drained. These accumulations are then able to support plant life and become soils.

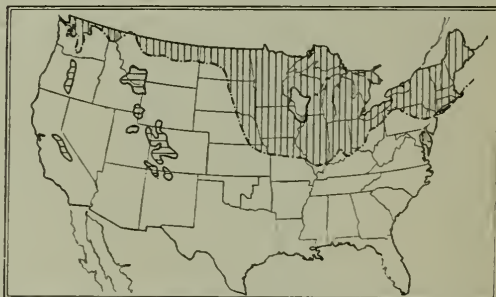
The marine soils occupy great strips along our Atlantic and Gulf coasts, making up probably one-twelfth of our land area. They are usually sandy in character, due to the washing of the waves and the extreme solvent action of the water to which they have been so long exposed. They are the poorest of our large soil provinces. The lake soils are found along our Great Lakes and in the Red River Valley. They are rich, due to their favorable location and organic content.

The soils of the Red River Valley are extremely fertile and exist under such climatic conditions as to be adapted especially for spring wheat.

Ice and wind-formed soils

The grinding power of the ice when in large masses has been described. We already have been told how centuries ago, probably before the advent of man, climatic conditions were such that North America was covered by a great ice cap of tremendous extent. In depth it often exceeded two or three miles. The pressure behind this ice mantle pushed it slowly forward. If its front did not melt too rapidly, this great glacier invaded the country to the southward. If the rate of melting exceeded the forward movement, the tortured earth was liberated from its deadening grasp.

How long the ice continued to occupy our continent it is difficult to estimate.



From Lyon, Fippin and Buckman's *Soils, Their Properties and Management*, The Macmillan Co.

THE ICE SHEET IN NORTH AMERICA

During the Glacial Age immense sheets of ice invaded what is now northern United States. The debris left behind when these great continental glaciers melted away now forms the fertile soils of the immense and varied area outlined on the map above.

Suffice it to say that this oscillating ice mantle existed long enough to grind to powder an immense quantity of the underlying rock and to mix with it the original soil covering. As the glaciers retreated the product of this great ice mill was deposited over the area so cruelly gashed and scoured. Their work, while at first one of destruction, has been of wonderful profit to our agriculture. This freshly ground debris carried a great quantity of plant food and as soon as the climate changed and plants were able to exist it was resolved into fertile soil.

The glacial soils cover the whole northern part of the United States. Their southern extension is roughly defined by a line drawn from New York City to southern



Photo by Will H. Stokes

MOCCASIN BEND FROM LOOKOUT MOUNTAIN, CHATTANOOGA, TENNESSEE

In the lower courses of a river the current generally becomes sluggish and the stream begins to swing from side to side in great curves, depositing sediment on either bank. Our most productive farms are often on such soil.

New York state, thence southwest to St. Louis and then northwestward up the Missouri River to the Canadian border. The soils do not contain very much sand and are often difficult to work. They are therefore called heavy soils. They vary in their fertility, some being rich and some poor according to the kind of rock from which they came and the climatic conditions under which they now exist. In general, their crop-producing power is above the average, and as they cover one-tenth of our landed area, their agricultural importance is very great.

After the great ice sheet had withdrawn into its northern fastness and before plants could obtain a foothold on the loose debris left by the ice, the wind was able to shift

a great amount of the finer material. Especially was this true in our semi-arid West. Much material was carried eastward as a fine dust and deposited where the climate became moist. Such wind-blown materials are found covering Kansas, Nebraska, Missouri, Iowa, Illinois, and parts of Ohio and Indiana. A great strip extends southward down the Mississippi River. This soil we have already spoken of as "loess." It is very fine, sticky when wet, and of a yellowish or buff color. It is very fertile and as it occurs in a region favored by rain it raises yearly immense crops. It is the great corn soil of our Middle West. Surely the wind has contributed something to our happiness and prosperity.



From Merrill's *Rocks, Rock Weathering and Soils*, The Macmillan Co.

SECTION OF GLACIAL TILL

Glacial debris when characteristically developed is deep and uniform bearing on its surface the soil resulting from the weathering that has succeeded the drastic action of the great ice sheet that brought it into being.

STRANGE THINGS LIKE MEN

The Curious, Intelligent and Terrible Creatures
which Are so Like and Yet so Unlike Us

THE LIFE-STORY OF MAN'S POOR COUNTERFEIT

MAN and the animals which most nearly resemble him — the apes, monkeys, and lemurs — form the first order of mammals. Man has naturally a place of his own in this work, and here are to be treated the great families of the animal kingdom which share the earth with him. While we shall not, in a popular work, follow the rigid classification of the scientists, we may glance, for a moment, at the arrangement of this first-class order upon which scientists have agreed. With man as the first family, the man-like apes form the second, arranged in three groups — the chimpanzee and the gorilla, the orang-utan, and the gibbon. In the third family are the Old World monkeys and baboons; in the fourth are the American monkeys; in the fifth the marmosets. This is the first sub-order of the Primates, and the lemurs form the second.

We shall glance here at some of the leading members of these various families of animals so nearly resembling man, representing something over two hundred known species. Many circumstances conspire to make the order the most interesting of all the divisions of the animal world. We no longer seek to hide the resemblance between the anthropoid apes and man; rather we take a fearful interest in tracing it. The man-like ape is simply a grim, repulsive caricature of man.

In the chimpanzee, which inhabits a fairly wide range of tropical Africa, the points of resemblance to man are more numerous than in any other of the apes. Its canine teeth are less formidable; there is less disparity in size between the adult

male and female; the bony protuberances over the eyes are less conspicuous; the whole structure of the animal, though true to the simian type, is less grotesque and forbidding than that of the gorilla or orang-utan. In height it is inferior to the gorilla, for, whereas the largest known chimpanzee is not over five feet high, a gorilla shot within recent years, near Tonsu, in the Cameroons, measured no less than six feet nine inches.

The body of the chimpanzee is thickly clad with hair of a dark hue, with lighter hairs here and there, and in some species is parted so evenly over the forehead as to suggest, at first sight, some attention on the part of the animal to its toilet. The ear is large and coarse, less like the human organ than the gorilla's, the nose is hopelessly depressed, and shorter than the gorilla's. The skin of the forehead is deeply wrinkled, and the animal has eyebrows and eyelashes. The chimpanzee, in common with the other apes, is tailless, but this animal has the arms shorter than the rest of the family. As the chimpanzee stands, its arms reach but little below the knee.

The home of the chimpanzee is the low-lying equatorial forests, but in one district it is found far up the tree-clad mountain-side. Though some chimpanzees will eat a mixed diet in captivity, all of them when at large appear to subsist upon the wild fruits which flourish about their homes. They will, however, boldly visit cultivated areas, attracted by fruits of which they are fond. This is the only time, in ordinary conditions, in which they are brought in conflict with human beings. They will

make their escape, if possible, but if brought to bay they will seize a man and inflict a terrible bite. Livingstone states that when compelled to battle for the protection of their young against a leopard they will bite off the paws of the assailant ;



CHIMPANZEE FEEDING ANOTHER WITH A SPOON

then retreat to a tree, moaning over their own wounds, and remain there until death releases them from pain. Though a slow-moving animal on the ground, where it can neither gallop nor run on all-fours, nor make progress upon its hind legs without support from its hands, the chimpanzee moves rapidly along the branches of trees.

The characteristics of the chimpanzee are best studied in captivity. Every zoological society of note has living specimens in its gardens, and it is generally agreed that the chimpanzee is a most intelligent and affectionate beast. With increasing years its temper may develop a certain sullenness, and its moods become a little dangerous, but to those familiar with its ways it is seldom very formidable. Many experiments have been made with a view of testing the intellectual capacity of this ape, and Professor Romanes succeeded in having the famous "Sally" taught to count up to five. If asked for any number of straws up to that total, she would place them, one at a time, in her mouth, and

when the requisite number was reached would hand the whole to her keeper. Afterwards, the keeper continued the tuition with a view to extending her knowledge of numbers to ten, but though she was, as a rule, infallible up to five, and fairly dependable up to six, beyond that the results were mainly speculative.

The educability of the chimpanzee is proved by the surprising performances of many animals exhibited at places of amusement. Bicycle-riding and roller-skating are among their accomplishments. They readily accustom themselves to clothing, to eating with a spoon from a plate or a cup, and, after a few lessons, they behave with the gravest decorum at table. One captive chimpanzee kept busy all day long in his room, using brush and duster, opening and shutting drawers and examining the contents, amusing himself by postures and grimaces before a mirror. This chim-



THE FAMOUS CHIMPANZEE "SALLY"

panzee was said to be actually a judge of human character, for a thorough but accomplished hypocrite, who deceived the keeper and others, was all along a horror to the chimpanzee, just as if he had seen through the rascal from the first.

Two surgeons, who were on good terms with this ape, did their best to overpower the poor brute and to operate upon it for abscesses, but this was impossible. Where force failed, however, persuasion succeeded. When the ape was quieted and reassured by the coaxing of his keeper, he allowed a further examination of the swelling, and even submitted, without twitching an eyelid or uttering a complaint, to the use of the knife, and other painful treatment. When this was done an unmistakable ex-

obviously with a view to the ape's treatment, would point with his fingers to the wounds, as though to remind his master of his duty.

This docility under treatment is characteristic of the grown chimpanzee, but if its trial should come early in life it remains to the end of its days a timorous, frightened creature, requiring the most careful handling.

Although three and a quarter centuries have elapsed since a white man first saw



© N.Y. Zoölogical Society. Photo Elwin R. Sanborn

YOUNG GORILLA, "DINAH," IN THE NEW YORK ZOÖLOGICAL PARK

pression of relief passed over the sufferer's face, and he gratefully held out his hand to both physicians, and embraced his keeper, without having been asked to do either. When other complications caused the death of this ape, he died fully conscious, gently and peacefully, not as an animal, but as a man dies.

Another chimpanzee which was suffering from two abscesses on the neck, would sit up without restraint to be surgically treated, and as his keeper approached,

a gorilla, we still know surprisingly little of the habits of this man-like monster of the woods. The reason is that the gorilla makes its home in the dense forests of Equatorial Africa, in a perpetual twilight, and in an atmosphere like that of a conservatory devoted to exotic plants. The climatic conditions are almost intolerable to a European, and even if these be borne the surroundings are so dark and gloomy that careful observations of animal life can only be made with extreme difficulty.

No adult specimen of the gorilla has ever been seen in captivity, and it is unlikely that any ever will, for such is the giant strength and ferocity of the animal when assailed that even men who have lassoed the unruly rhinoceros and roped lions in their lairs, shrink from the task of making prisoner a full-grown gorilla.

Travelers' tales that had gathered about the gorilla now discredited

The usual number of travelers' tales have gathered about the gorilla, such as his beating elephants with clubs, his capturing men and women, his seeking the natives' fire when its owners have quitted camp, but all these, with the stories of his unprovoked savagery towards all other forms of animal life, have been contradicted by the reliable data which, piece by piece, have been gathered to form the sum total of our present knowledge of the beast.

It was long believed that the gorilla dwelt invariably in trees, or that the female with her young made her rude resting place in the tree while the male reclined, lightly sleeping, on guard at the foot, but we now know that the gorilla will, at times, roughly bind together a platform of vegetation on the ground, and there pass the night, with the female and young similarly accommodated close by. That these animals are proficient climbers is beyond dispute, and their physical equipment, despite the vast bulk of the male, is ideally adapted to arboreal existence. The huge hands and the prehensile feet, the enormous power of all four limbs, supported by a frame of incomparable strength, render the gorilla the king of forest life.

The hideous monster of the forest that in some ways resembles man

A full-grown male gorilla may measure six feet nine inches in height and weigh 450 pounds. The females, however, are much smaller, rarely much over four feet in height.

Happily, in the haunts to which he is restricted, there is little to challenge his supremacy. In his steaming forests little more than the occasional note of a bird

gives suggestion of life other than his own and the mightiest of the Primates lives, with his mate and offspring, solitary and terrible, a nightmare representation of the handiwork of nature in horrific mood. This hideous monster of the forest twilight approaches in the shape of the brain and ears more nearly to man than any other of the apes. Like the chimpanzee, its wrist is fashioned on exactly the same plan with our own, a respect in which it differs from the other Primates. It has a better developed calf than the other apes, and, though it has one pair of ribs more than man, it agrees generally with the rest of the simian family in its extraordinary structural resemblance to human beings. The prominent brows, and the immense tusks, or canine teeth, the hideous, broad, flat nose and protruding jaws, give it, however, an entirely unhuman appearance.

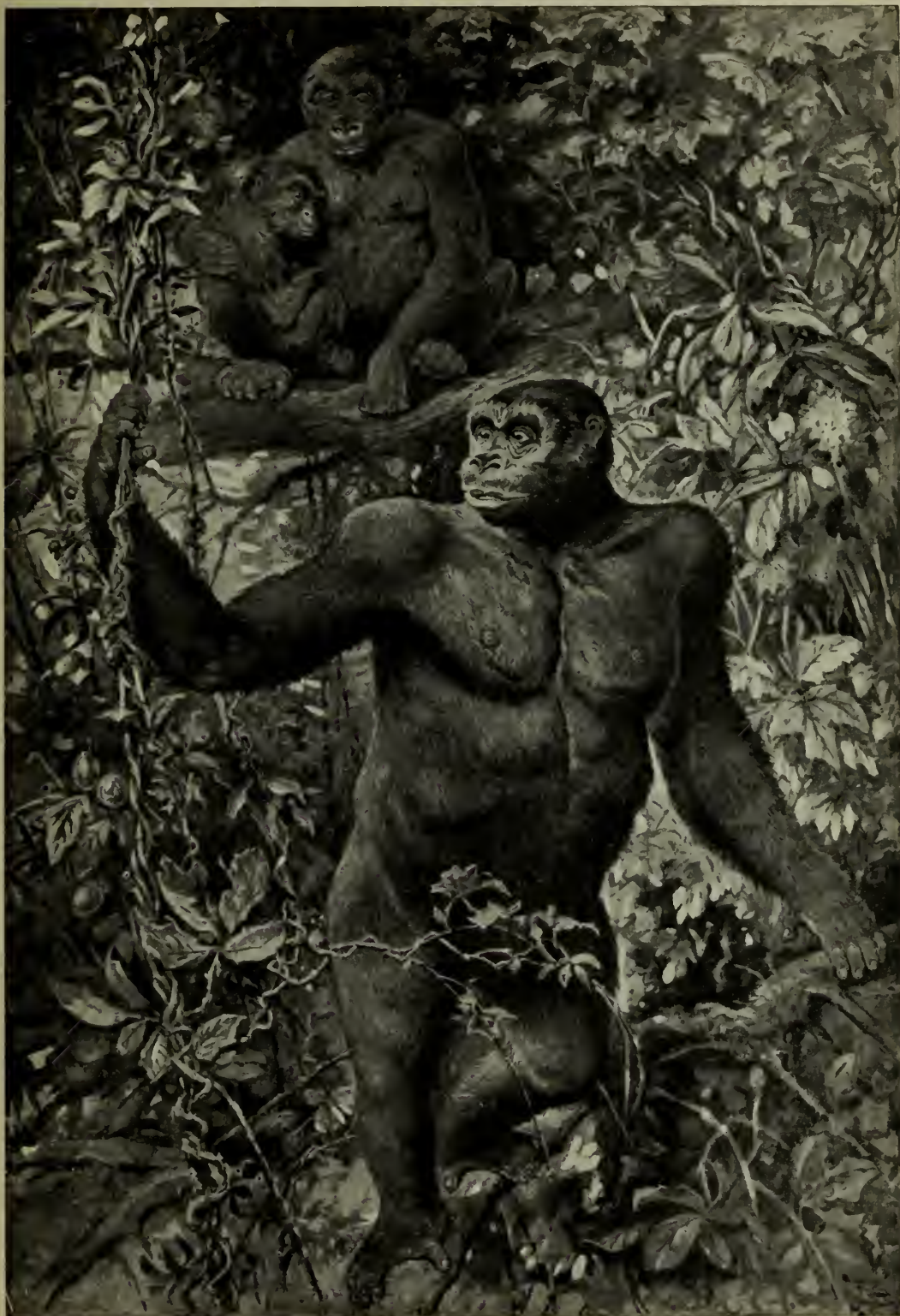
The fear of the gorilla that will drive it from man's presence

It is a convention to declare the gorilla invincibly savage and wantonly ferocious, but later light upon the subject shows that it shares the nervous abhorrence of man common to the majority of wild animals, and that it will flee his presence as rapidly as the most timorous monkey. If unable to escape, then its rage is undoubtedly fearful; and at close quarters its mighty grip and terrible teeth make it a foe whose proximity the stoutest hunter might be glad to avoid. But the nature of the brute is not to be judged from conditions such as these; even a rat at bay will fly at a man's throat. The young gorilla is remarkably docile, tractable, and gentle in captivity.

A young gorilla on board ship which knew it was doing wrong

All hope has been abandoned of rearing a gorilla in confinement, unless the creature has been kept captive near its birthplace, and slowly accustomed to hand-feeding and restraint, before being submitted to the ordeal of travel and strange food, leading to quarters in a climate as unlike that of an African forest as a summer's day is unlike mid-November.

THE MAN-LIKE MONSTER OF THE WOODS



THE GORILLA, THE TERRIBLE CREATURE THAT HAS NEVER BEEN CAUGHT ALIVE FULL GROWN
The gorilla makes its home in the twilight of dense forests. So terrible in its strength is this wild creature that men who have lassoed the rhinoceros and roped the lion shrink from a full-grown gorilla.

However, though experiences with the gorilla in captivity have been unfortunate we know sufficient of the disposition of the animal, in its tender years at all events, to realize that it possesses a type of mind similar to that of the chimpanzee, readily acquiring habits of sociability, good table manners, and the desire to romp and play with human beings. Something of the roguish guile of the child was displayed by a young specimen taken to Germany.



AN ORANG-UTAN TAKING A WALK

This little creature was practically free of the ship by which it traveled, and was a general favorite. When it desired to have sugar or fruit, which it knew to be stored in a certain cupboard, the gorilla would suddenly quit its play and pretend to go in an opposite direction, only altering its course when it believed itself to be no longer under observation. Then it would dart to the cupboard, open the door, and with a dexterous snatch secure the article of which it was in search, sometimes closing the cupboard door before enjoying its plunder, or, if discovered,

making its escape with its booty. The whole behavior of the animal, at such a moment, made it clear that he was conscious of wrongdoing. Another young gorilla that died shortly after being brought to America was kept as a pet in a London household for three years where it was trained and behaved much like a child, having the run of the house with a room and bed of its own. It was very fond of children and seemed dependent upon human companionship. Indeed its death was due largely to homesickness when it was taken to the United States by a total stranger. Describing in the *Zoölogical Society Bulletin* for September, 1921, some of the clever performances of this intelligent animal, Alyse Cunningham, who took care of him, states:

"He was especially fond of my little three-year old niece, who used to come with her mother to visit. John (the gorilla) and she used to play together for hours and he seemed to understand what she wanted him to do. If she ever cried, and her mother would go and pick her up, John would always try and nip the mother or give her a slap with the full weight of his hands, evidently thinking that she was the cause of the child's tears.

"One day when we were going out John wished to sit on my lap. My sister said:

"Don't let him, he will spoil your dress."

"As my dress happened to be a light one I pushed him away and said: 'No!' He at once lay on the floor and cried just like a child for about a minute. Then he rose, looked round the room, found a newspaper, went and picked it up, spread it on my lap and climbed up. This was quite the cleverest thing I ever saw him do."

The long journeys of the orang-utan in the trees of its native forests

The "man of the woods," as the Malays call the orang-utan, is a native of Borneo and Sumatra, of powerful but ungainly build, distinguished from the other apes by its brown skin, red hair, and small ears. The arms are of such length that when the animal stands erect they reach almost to the ground. The short, thick legs are so fashioned that the knees turn outward,

with the result that the animal walks on the sides of its feet, with the soles turned inward. It is essentially a tree-dwelling animal, and travels considerable distances through the unbroken forests without descending to the ground. Though lacking the agility of the gibbon, it progresses at a surprising pace, without apparent haste, from tree-top to tree-top, testing each branch before transferring its weight to a new position. This method of progression would be impossible but for an abnormally long arm. The utility of these remarkable limbs is further evidenced by the animal's way of gathering food from extended slender boughs upon which the entire weight of its body could not be borne.

Structurally the orang-utan is in some particulars less like man than are the chimpanzee and the gorilla, but in its "human" attributes it approaches as closely to the human as its relatives. The young orang-utan displays a lively affection for human beings; and though it may be rather difficult to manage as it advances in years, it remains still a playful beast, a romping child in the guise of a monster. Dr. Alfred Russel Wallace's story of his attempt to rear a young orang-utan reveals traits in the animal which could not but recall to the philosopher's mind those of a human child. The animal cried and screamed when placed in its cradle; it showed unmistakable satisfaction when nursed and fed, but resented with vehement protest any attempt to impose upon it food it did not like. It was happy in its bath, happier still when having its coat dried and brushed. The young orang-utan, like the young of the other man-like apes, is comparatively helpless; it owes its safe emergence from the perils of infancy to the care and affection of its mother.

The orang-utan in captivity shows nothing of the ferocity which at times characterizes the adult when at liberty. It is fair, then, to assume that the orang, though conscious of its great physical powers and its ability to inflict injury with its huge teeth, is by nature peaceful and gentle, unless provoked to rage by interference or attack.

No reference to the orang-utan would be complete without mention of the famous "Jenny" which the London Zoo once possessed. This animal, like those now in captivity there, showed distinct traces of humor and an absorbing love of play. By its gentleness and appealing ways it en-



TWO STUDIES OF THE ORANG-UTAN

deared itself to a distinguished circle of human admirers, among whom was Sir Richard Owen. A fascinating little picture occurs in Owen's biography, descriptive of a Christmas morning visit to Jenny:

"She certainly attempts speech as far as her powers admit. When she is fond of a

person, she puts her long, strong arms round his neck, and makes a curious noise, like an attempt to utter caressing words, opening the lips and moving them, as though trying to make certain sounds. She produces a sort of murmur, which one might easily translate into kind expressions. Today she took a fancy, when out of her cage, to look out of the window, and slyly creep along till, under the pretense of friendship, she got there. The keeper pretended to be offended at her not coming when he called, and she ran up to him, put her arms about his neck, whispering to him and kissing him, till he seemed to forgive her."



THE LONG ARM OF THE SILVERY GIBBON

The gibbon, although it is the only ape which habitually walks in an upright position, is the least exalted of the higher apes. Its head is the most human in shape, but it bears the mark of the monkey in the form of naked patches upon the buttocks. The body is short and light, and the arms are so long that the ape, as it walks, can touch the ground with its knuckles. But it has progressed beyond need of assistance of that kind. It shuffles valiantly along with head erect, using its arms as balancers, unless there should be some convenient overhead support, when it will grasp that support, be it bough or bar, as an additional help. The largest of the gibbons, of which there are eight species, is only about three feet high.

When moving about on the ground, the gibbon always appears in a desperate hurry, as if afraid its head might reach its destination in advance of its feet, and as it shuffles briskly along, with its arms waving ludicrously in the air, one might fancy it a child in furry "tights," balancing a heavy weight on its head. But, if awkward and uncertain when on foot, the gibbon is master of a form of poetry of motion when at home in the trees of its native forest. All the members of the family — which is restricted to the warmer parts of southeastern Asia — are expert climbers, but the agile gibbon, in its swift, unerring flight from tree to tree, has no rival, save the birds. The lightness, grace, ease, and speed of its progress are indescribable. When on the move among the trees, these apes do not climb with the caution which characterizes the movements of the other apes; they spring from bough to bough with amazing strength and speed. Hanging at full stretch by one hand, they leap to a distant branch, which they catch with the other hand. Without an instant's pause a second leap follows, when the hand first used is again brought into play, and then on uninterruptedly, each hand employed alternately, the leaps covering from ten to thirty feet, according to the distance of the bough at which the gibbon aims.

Any one of these longer aërial flights would be astonishing, but one marvel follows another until the eye of the observer can scarcely follow the flying animal. The absence of effort with which the jumps are made, the rapidity with which a bough is specially selected, so as not to check the swing of the flight, the ease with which the creature can twirl itself round a branch, sit at ease, and resume the journey without a second's delay, are achievements which leave the most accomplished human gymnast dumbfounded. As we watch its passage through the air, we are not surprised that this animal should be able to catch a bird on the wing, a feat of which there is more than one record. The exploit suggests a purpose, and it is a fact that the gibbon, while mainly a vegetarian, will eat young birds as well as insects.

THE ANIMALS MOST LIKE MEN



ORANG-UTAN AND CHIMPANZEE



CHIMPANZEE EATING TOGETHER



CHIMPANZEE FRIENDS



A CHIMPANZEE ON THE WATCH



THE CHIMPANZEE ERECT



ORANG-UTAN UP A TREE



THE CHIMPANZEE EXPECTANT



A BABY GORILLA



THE SILVERY GIBBON



THE HOOLOCK GIBBON

SOME TYPICAL MEMBERS OF THE FOUR FAMILIES OF MAN-LIKE APES

Though gifted with a less highly organized brain than the rest of the apes, and disposed to overpowering nervousness which impels it to bite even those with whom it is ordinarily on most friendly terms, the gibbon is gentle and affectionate, and makes



APES PLAYING IN A TREE

an engaging pet for those whose nerves are proof against the extraordinary volume of its cries in the morning and at night.

Nature has been prodigal in plan and invention in dealing with the monkey groups. Nearly all the colors of the rain-

bow seem to have been given to some members of the family. We find them with flesh-colored faces and hands, and nails as rosy and daintily shaped as any that have received the attention of the manicure. They are black faced, gray faced, brown faced; whiskered, smooth, and puckered; some with elastic cheek pouches, into which an assortment of food may be crammed for future use. They vary in size from that of a well-proportioned mastiff down to the modest dimensions of the squirrel. Some have tails of great length and stoutness, some have tails as short and misshapen as that of a thoroughbred bulldog; others have no tails at all.

Nasal organs of all sorts and sizes and shapes appear among them, from the little snub nose, hardly worth calling a nose at all, to the formidable organ of the proboscis monkey, which must at one time have had a reasonable chance of developing into a trunk. But there is one feature concerning the nose which is always constant. To the Old World monkeys and baboons the term "catarrhine" is applied; the New World monkeys and the marmosets are grouped as "platyrrhine." The noses of the former have the nostrils close together and directed downward; the nostrils of the New World monkeys and marmosets have the nostrils widely separated and directed outward. We have three clear points in respect of which the Old and the New World monkeys differ. There is this difference as to the formation of the nose; there is the fact that only American monkeys have prehensile tails, and there is the fact that, although not all Old World monkeys have cheek pouches, *none* of the American species have them.

The Old World monkeys and baboons constitute the third family of the Primates, and are in eleven groups. First in our classification come the langurs, which, abounding in India, Ceylon, and Burma, are found also in part of China. There are fourteen species, all of slender build, with tails which may sometimes exceed the entire length of head and body. The best known of the genus is the hanuman monkey, the animal which every pious

EMOTIONS EXPRESSED BY ANIMALS



CONTEMPT



THOUGHT



SURPRISE



PERPLEXITY



SUBMISSION



MISERY



INTEREST



FEAR



SATISFACTION

The man-like ape is a grim, repulsive caricature of man; and yet is capable of expressing emotions but little less clearly. In these pictures the whole emotional gamut is run, from contempt to satisfaction.

Hindu holds sacred. The consideration and friendship which he has experienced at the hands of the natives have made the hanuman the boldest of monkeys, and Hindu piety has been sorely tried, as troops of these animals have raided stores and shops whose owners dare not, for the sake of their faith, engage in reprisals. This monkey, great thief as he is, makes some return for the toll that he levies, for friendship towards man seems now inherent in this species, with the result that in the wildest forests, remote from city life, the hanuman regards the appearance of human beings with favor, and, hovering overhead in the trees, is an infallible monitor when a tiger is in the vicinity.



THE YELLOW BABOON
Which steals the crops in West Africa.

When we reach the true baboons, we find nature in her wildest, most garish mood. The baboons are the lowest of the Old World monkeys, and the Greeks and Romans recognized the canine character of the head and muzzle when they named them the "dog-headed" baboons. Their coarse, elongated heads, armed with teeth as formidable as many a carnivore's; the all-fours gait permanently adopted; the vivid colors of the naked buttocks and muzzle, conspire to make the baboon one of the most hideous of living animals. There are six species of baboons in all, each one confined to the Old World, but excluded from the oriental region.

They live in herds of varying numbers, experience having taught them the value of coöperation, whether robbery of cultivated plots be their object, or defense against a common foe. Although in the main dependent upon a vegetable diet, they will eat practically anything, from lizards, birds and their eggs, to ants, scorpions, and centipedes. They are four-handed like the rest of the monkeys, but their extremities are better adapted to progress on the ground than to arboreal life. Some of them are very poor climbers, although this does not apply to their performances among the rocks, where they can travel with astonishing speed. In the open they never adopt the upright gait, except when sitting at rest or brought to bay. At bay they sit up, and an assailant realizes that the fore-paws which have so swiftly carried the animal in its flight, have suddenly reverted to the function of hands — excellent grasping implements by which a victim is drawn with great force to the baboon's terrible jaws. It is one of these animals, the mantled baboon, which we find sculptured on Egyptian monuments, and this animal was among those revered and accorded funeral honors. Nevertheless, the Egyptians combined utilitarian ends with their veneration, for sculptures show us that they taught the baboon to climb trees and hand down the fruits to slaves waiting below. The range of this particular species embraces the countries bordering on the Red Sea littoral and the Upper Nile valley, but the baboon tribe is widely distributed over the whole of Africa, the bold and pugnacious chacma in South Africa, the yellow baboon in West Africa, the mandrill in western equatorial Africa, forming conspicuous features of the fauna of the Dark Continent.

The mandrill is, indeed, one of the show-pieces of the African continent. A beast of immense power and ferocity, he equals in grotesqueness the wildest imagination of the artist in mythological creations. With its extraordinary coloration, this animal is quite without parallel among mammals. Its jaws are little less to be feared than those of the leopard, against

which mandrills combine for defense. Its limbs, though comparatively short, are massive, with ample bone and magnificent muscle. Brutal and revolting as is the mandrill's appearance, the animal commands respect for a high type of intelligence. The same may be justly said of all the baboons, for, though they are the most repulsive of all the Primates, they are entitled to consideration as having distinctly developed their brains. They dwell in the midst of powerful carnivorous enemies — lions, leopards, hyenas, and jackals — yet such is their courage and skill in concerted defense that they survived the perils of the ages, to remain today a force with which the cultivators of the soil have seriously to reckon.

The spider-monkeys are as much superior in point of activity to the rest of the monkey world as the agile gibbons are superior to the rest of the apes. But their preëminence arises from a different qualification. The gibbon's hand is a better instrument than the hand of this monkey, in whom it serves for little more than a hook by which to swing from branch to branch. The tail is, however, a remarkable instrument, furnished with so keen a sense of touch that with it the monkey can convey food to its mouth, or use it as an instrument for extracting food which the hand cannot reach. Most important, however, is the function of the tail in climbing. The spider-monkey uses his tail even more than his limbs in making his way about the trees in which he lives. The tail grips whatever it touches, so that observers have declared that it might almost possess the gift of sight. By its aid the monkey can hang head downward, can drop considerable distances, and catch a lower branch without the employment of hands or feet; while in making prodigious leaps from tree to tree the animal relies fully as much on the grip of the tail as on feet and hands for its safe landing.

The term "spider-monkey" describes, it is scarcely necessary to add, not the habits of the animal, but the character and action of the limbs, which are long and spider-like. It is not a little singular that the spider-monkeys, though so wonderfully adapted

to arboreal life, are more at ease upon the ground than many of their congeners, assuming an upright gait, and using the tail, curled into the form of the letter S as a balance.

The howlers remain to be noticed. Six clearly defined species are known, each distinguished above all other Primates, except the gibbon, for the power of its voice and the persistence with which the creature exercises it. Sunset and sunrise are alike proclaimed in deafening chorus, in which one voice of special resonance is said to lead. Less active than the spider-monkeys, the howlers have prehensile tails, and use them to bridge gaps between one tree and another. They move over the



THE BROWN SAPAJOU
A typical South American monkey.

tops of trees in orderly procession, an adult male generally leading a party of females, some of which carry their young on their shoulders. Arrived at a point at which the branches of neighboring trees do not touch, the leader suspends himself by his tail, and, letting himself down, swings to and fro until he is able to grasp the neighboring branch. The rest of the party follow suit, one by one, each at the point chosen by the patriarch of the family.

The true Primates end with the marmosets, which resemble squirrels in form and habits; but, though the nails are so unlike those of the monkey as to be true pointed claws, instead of flattened nails,

the face is that of a tiny monkey, and the teeth are thoroughly ape-like. The female gives birth, as a rule, to a litter of two or three, therein showing more affinity with the lower animals than with monkeys, which usually give birth to but a single young one at a time. The marmoset, though nervous and apt to bite when alarmed, is popular as a pet, and native women are known to carry these little animals about in their bosoms.

Relegated to the second sub-order of the Primates, the lemurs and lemur-like animals are one of the most interesting sections of the animal world. Superficially the resemblance to the monkeys is not at once conspicuous. The lemur head is fox-like, and devoid of expression; the general form and gait suggest the true quadruped. But the points in which the anatomy of the lemur agrees with that of the monkey leave no doubt as to the lemur being rightly included in the group of animals all four of whose limbs terminate in prehensile hands. Some fifty species of lemur-like mammals are in existence, but though a few strange examples of the order may be found in Africa, in southern India and Ceylon, in the island of Celebes and the Philippines, the real home of the group is Madagascar.

The ghostly nocturnal movements of some of these silent-creeping animals, coupled with the glare of their large staring eyes, fill the natives of Madagascar with a superstitious awe which is the protection of the lemur, and accounts for its abundance in Madagascar, where every thicket is said to contain at least one.

We find a striking variety of size, form, and habits among the lemurs, many characteristics quite unexpectedly appearing in the group. From the adult indri, which measures two feet from nose to root of tail, we range down to the mouse lemur, which is almost as small as its name implies. We have lemurs whose agility challenges comparison with the monkeys; and lemurs, such as the slow lemur and the loris, whose movements are a model of deliberation; lemurs which walk by day, lemurs which creep by night; herbivorous lemurs, carnivorous lemurs; noisy,

boisterous lemurs, and lemurs which never utter a sound except when angered or alarmed; lemurs which refuse to quit the trees unless compelled to cross a bare patch of ground to fresh quarters, and lemurs whose habitat is rocky enough to rejoice the heart of a baboon; lemurs with long and bushy tails, lemurs with short and stumpy tails, lemurs with no tails at all. In fact, nature seems to have rung the changes upon lemuroid forms as completely as upon the pouched mammals of Australasia.

Some attempt has now been made to pass in brief review the chief groups into which the various Primates fall. It remains to see to what extent these animals resemble man in points other than physical. The lemurs and marmosets may be left out of account, for, the lowest in physical and mental organization, they are the least intelligent of the great group to which they belong. The psychology of the monkeys and apes is, however, quite a different matter.

The ape brain is, after that of man, the highest, and it would be presumptuous to declare it incapable of further development. With all his mental limitations, the monkey shows strikingly human traits, and even his ill-temper in captivity and his inability or unwillingness to learn, are explicable on other grounds than that of lack of intelligence.

The monkey's perceptive faculties are exceptionally keen. It distinguishes instinctively between those whom it has cause to fear and those whom it has not. A distinct evidence of this was afforded by a monkey which escaped from the establishment of a dealer in wild animals, and betook itself to the housetops. It was in vain that the proprietor and his assistants sought, by every persuasive method known to them, to get near the fugitive. He knew the meaning of their blandishments, and refused to be charmed. But he went voluntarily, day after day, to backyards and street corners where children offered him food; he paid daily visits to a restaurant where patrons threw him morsels; he went down to casual sympathizers in the streets who had nuts and

other delicacies with which to solace his solitude. But not an employee of the firm to which he belonged could get within arm's length of him; and ultimately the dealer, fearing to trust so powerful a creature to unfettered liberty, caused the poor beast to be shot.

The keeper of the apes at the Bronx Zoo, who gets many things done by his charges at the word of command, is too wise to believe that apes or monkeys really understand human speech, but they undoubtedly appreciate the meaning of different tones of voice, he says. If an officer says "Attention" to a squad of soldiers, and next "Double-quick," it is the difference in tone rather than the words used

same inquisitiveness, as every hunter knows, but the monkey has the quality in irresistible measure. The monkey's love of fun resembles that of some mischievous rowdy, as when it snatches the property of some kindly visitor, or knocks off the hat of the man who has fed it.

It is hard to say where reasoning affection ends and blind instinct begins when the emotions of a monkey are concerned. Its natural affections are of the strongest, so strong that while it will endure immeasurable misery and suffering for its living offspring, that affection persists even after the life of the offspring is ended. Some monkeys will carry a dead young one for weeks.



RED-FACED SPIDER-MONKEYS



THE QUAIN TARSIIERS, COUSINS OF THE APES

that conveys the meaning; and that is doubtless the way orders with which they are familiar act upon the mind of the apes. That seems plausible enough. An organ-grinder's monkey was climbing a wall covered with Virginia creeper, to the serious detriment of the vine, when the owner quietly protested. The grinder gave a tug at the monkey's chain and the animal sprang down; then, rushing away from its master, the creature bit the leg of the gentleman who had spoken the words which had brought his climb to an end. It is reasonable to suppose that the monkey traced effect back to cause, that being the tone of the words he had heard.

The monkey approaches human beings in curiosity. Other animals have the

A different type of affection is aroused, however, when a man is concerned. A good example is that classic of monkey fidelity which saved the life of one of its keepers. The keeper had to enter a cage in which were a powerful baboon and a small monkey, the monkey being in constant terror of the larger animal. The baboon made a sudden attack on the man, and fixed its terrible teeth in the back of his neck as he knelt on the floor of the cage. The keeper was a special favorite with the small monkey, and, seeing his peril, the little creature mastered its horror of the baboon. Leaping upon the baboon's shoulders, it succeeded in making the animal release the man, enabling him to escape, badly hurt, but alive.

THE PRIMITIVE MAN OF ICE-BOUND EUROPE



It is thought that such men as this, very modern in type, may have survived the Ice Age in Europe, a period of perhaps thousands of centuries.

DID MAN HAVE AN ANCESTOR?

The Mystery of Man's Beginning and his
Achievement of Supremacy in the Animal World

THE FIRST KNOWN MAN IN THE WORLD

CURIOSITY is one of nature's contributions to all humanity. It is as characteristic of the senile man as of the developing child, and were we to live a thousand years instead of the proverbially allotted "three score and ten," it would be perfectly natural for each of us to be curious over something or other even to our dying moment. We are curious of this, that and the other reality — or fancied reality — and when our mind is finally set at rest by a logical explanation of some strange problem, our inquisitiveness immediately presents us with some new perplexity to be curious about.

One of the things that has aroused the curiosity of man and troubled his mind since time immemorial is: "Where did man first arise, and how?" and "Who, if any, were his ancestors?" These and other questions as to our origin can be easily asked, and we can speculate and theorize as to the correct answer, but when all is said and done we are no nearer to a satisfactory and provable answer than we are to the explanation of just what insanity is. Medical science has revealed to us a lot of truths, but the problem of insanity, with its how, when, where and why, has never been so cleared up as to tell us just what and where the trouble is and how the remedy can be quickly and effectively applied.

Everyone is entitled to his or her opinion but that opinion cannot be thrust upon everyone else. Mankind may be considered a product of "special creation" or a product of gradual "evolution" from some lower form. Whatever view is accepted must be based upon conscientious

ideas, since mere opinions differ and science has no authoritative answer to give. In what follows we shall endeavor to set forth various views, among which are those of some investigators who maintain that mankind and the anthropoid apes have had a common ancestry.

Supposing, then, as some believe, that mankind is not a product of "special creation," but of growth and development, as we know every individual man to be, we must turn, with a quite new kind of interest, curious and sympathetic, to the lower animals. We can then no longer distinguish them as "the animals," as if man's body were not itself an animal. We must call them the "lower animals," and we must look at them not only for their own sake and their own interest, but with a personal interest also. Like ourselves, they are born to die; they are largely subject to our infirmities, and we to theirs. And some people would even have us believe that the blood of lower animals can replace and supplement our own when we are in the grip of disease-microbes and require a blood transfusion to save our life, that our relation to them is not merely a matter of parallelism, but that it is a blood relationship in the profoundest sense of the words.

But this is not the case, for medical science has shown that all human blood falls into four different types; that when an individual is in need of a transfusion of blood, the blood of the "donor" must not only be human but, in addition, it must be of the same type as that of the "recipient" or of a type that will not cause hemolysis of the red cells of the re-

cient's blood. The modern study of our minds, also, and especially of the roots and springs of our conduct, has combined with the more intelligent study of animal conduct and feeling to show that we are superior to the lower animals in mind as well as body.

The study of the animal world as a whole has incalculably gained in dignity, in importance, and in human interest through these revelations of the past half century. And thus, also, the study of man must first begin with as close an inquiry as possible into the simpler structure of the lower animals. Let it be insisted not only that all life is one, but especially that all animal life is one. Hence, while it remains truer than Pope could realize that "the proper study of mankind is man," no modern writer on man does his duty who does not insist that the study of man is necessarily imperfect, and therefore less than proper, if it omits also to study life as a whole, and especially the lives, history, character and conduct of forms lower than man upon the earth.

Man may not have sprung from earth full panoplied, like Athene from the head of Jove, and he must then consent to survey "the base degrees by which he did ascend," even though the subject should be distasteful; even though he may be inclined to share the furious indignation of Carlyle when anthropoid apes were first exhibited at the London Zoölogical Gardens, or the disgust which many sensitive men and women feel today at the spectacle of these hideous parodies, as they appear, of mankind at its worst. Those who would have it that mankind and the apes had a common ancestor say that "only man and monkeys (including apes) have an instinctive fear of snakes; that rats, rabbits, goats, ducks, pigeons, and so forth, have neither a dread of snakes nor a prevision of the swift death that may come to them." But this is far from the truth, for even hens and turkeys will show their fright when they see a snake; furthermore, the little child has no instinctive fear of a snake, but acquires its fear later through the warning admonitions of adults or through experiences of its own.

But there is a large and most important group of diseases to which only man and the anthropoid apes are subject. The lower monkeys are as immune to infection by these diseases as, say, fish or birds are, but man and the apes promptly succumb. This extraordinary fact leads physiologists to believe that the blood of man and that of any of the man-like apes are practically indistinguishable by the tests which will immediately and certainly distinguish the same blood from that of any other animal. The scientific interest of the fact is evident, and its medical and legal interest is scarcely less. For the expert, to whom there has been submitted a blood-stain from a suspected murderer's coat, or from a knife, would be able definitely to disprove the assertion that it is the blood of a dog or a pig, and could say that it is the blood of either a human being or an anthropoid ape. Then he would immunize a rabbit or a guinea-pig against human blood. This done, he would take some serum from the immunized animal and bring it in contact with a solution of the suspected blood in a 0.75 per cent salt solution. Human blood will give a precipitate at the point of contact, other blood will not.

It may also be added that this is of medical as well as of medico-legal interest. The pioneers in the modern control of disease are long past troubling to argue as to the relation between sin and disease, or between man and the lower animals. They know that much disease can be controlled by the kind of knowledge which can be obtained by observation of apes. But apes are scarce, and the men who are fighting disease have not so much money at their disposal as the show-men who exhibit performing apes for gaping audiences to wonder at. The arrival of an ape that could be bought within reason has before now led to keen competition among men of science, who knew that this creature might give them the key to the relief of some terrible malady of man. Already within the past century Metchnikoff, at the Pasteur Institute, has made a great stride in the control of disease by his studies on the relationship of diseases between man and the chimpanzee.

We have made some brief mention of these facts because they are of recent discovery and were, of course, wholly unknown to the evolutionary pioneers of the nineteenth century. Their chief interest may be practical, but they are also of biological importance to man, and therefore demand a place in that connection.

Let us now set ourselves to the destruction of a popular notion to which too many writers have loaned currency, and which has led, and still leads, to all manner of

false arguments and wild-goose chases, not to mention our undue disgust when we contemplate a cage full of orang-utans or chimpanzees. It is the notion that man is descended from these animals, that his "first parents" were

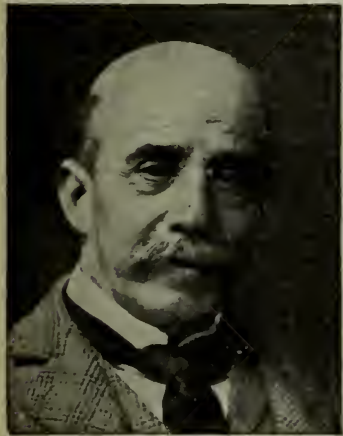


Photo Elliot & Fry

PAUL DU CHAILLU
Discoverer of the gorilla.

just such creatures, and that not only should he therefore be ashamed of himself, but he should also be able to find the "missing link" between these creatures and himself. But this disgust, wherever it may exist, is really uncalled for; the search for the "missing link" is futile, and arguments based on its discovery are worthless, for the excellent reason that in spite of many anatomical resemblances, the apes are not man's ancestors.

Darwin's only reference to this subject in the "Origin of Species" consists in a simple short sentence saying of his inquiries that by them "much light will be thrown on the origin of man and his history." He said no more. He said no less, because he thought silence would be dishonest. Twelve years later, in 1871, he published his "Descent of Man," and meanwhile Huxley and Haeckel had shown what the doctrine of evolution meant for our "theory" of man.

Many lesser students have since contributed to the literature of this fascinating and all-important subject, but neither the pioneers nor any writers who knew anything of the subject have ever asserted or suggested anything so palpably impossible as that man, so highly specialized, could be descended from any of these anthropoid apes, all of which are so highly specialized in their own way. That is the purest nonsense, with no authority anywhere to support it.

Our ancestors were not chimpanzees or orang-utans. Further, though we continue to look for and expect to find any number of fossil remains which suggest and amplify our knowledge of man's ancestry, we shall never find any



M. ALEXANDRE EUGÈNE DUBOIS
Discoverer of the so-called "Java Man."

"link" between us and the anthropoid apes, but the absence of such links is no sort of argument against the evolutionary theory of man's origin.

Now we are in a position to make a beginning. Naturally, the first step is to study, more minutely than in any other case — and also more urgently, for the animals are disappearing — every feature of body and habit and character, of diet and gesture and incipient speech, and domestic and all-but-social life, which these kinds of animals display. They must be studied in their native homes in Asia and Africa — for none are to be found in the New World, a point of enormous importance — and also they are to be studied, in other aspects, as we see them in zoölogical gardens and menageries. Some may be content to study them only in their "act" in the vaudeville shows, for which promising young chimpanzees are trained to smoke and drink; and thus,



SCENE IN THE ISLAND OF JAVA, WHERE THE REMAINS OF THE SO-CALLED "APE-MAN" WERE FOUND

having proved themselves practically human — as humanity is exemplified and understood in such places — can earn a thousand dollars a week, until the tubercle bacilli in the atmospheres where they are exhibited make an end of them. Such intensely displeasing shows do certainly demonstrate the intelligence of these animals and provide for the psychologist most important data as to the degree and limits of their educability; but on all other grounds they are to be condemned, not least on the ground of the increasing rarity of these animals, and the priceless and unique services which they are able to perform for the study and relief of human disease.

Of the gorilla not much that is new has been learned since its discovery some sixty years ago by Paul du Chaillu, whose account was so long regarded as a trav-

eler's tale. The animal is exceedingly scarce outside its home in a small portion of Africa; and at the present moment, so far as inquiry shows, there are none in Europe. This, however, is the least important of the anthropoids from our present point of view, though it is, of course, very nearly the most interesting of all animals, and is treated as it deserves to be elsewhere in these pages. It has diverged much farther than the other anthropoids from their common stock, and it is found only in Africa. It approaches man only in the entirely unimportant point of stature, and, indeed, its tallness is one of the characters in which it is conspicuously unlike the other anthropoids, and far removed from the ancestral type. Some people suppose that the gorilla is nearer to man because it is tall, but its tallness really removes it farther from man.

Obviously, we must be guided in our search for a common ancestor (if there was one) by approaching as near as we can from both directions. We must study the most primitive and unspecialized types of man, and the most primitive and unspecialized types of apes. Our difficulties are serious, but they must be met, or posterity will never cease to blame us, for the chances of knowledge are passing. The primitive races of man, on the one side, and the anthropoid apes on the other, are rapidly becoming extinct. The time is not far distant when not a single living specimen of either is to be found, and the gap in living nature will then be a huge and incredible abyss.

Such study as has been accomplished points us to the past for evidence from fossil sources. Will we find something much more primitive than any existing men, and something much less specialized than existing apes? Fossil remains of man are found in various parts of the world, and fossil remains of anthropoid apes are found even in certain parts of Europe, where none of their descendants now live.

Of the ancestry of the gorilla we know nothing, and, indeed, it is only the gibbon that provides us with much fossil evidence. This creature, preëminently the tree-ape, as its scientific name implies, does indeed concentrate upon its small self the interest of tracing backwards the anthropoid ancestry.

As for man's remains, the number of which is constantly receiving remarkable additions — not least in Europe, though Europe was not his birthplace — we can indeed point to the evidence of skulls which show a formation of the cranium and the jaws more nearly resembling those of the apes than we find in any existing race.

But this evidence, however, though of enormous interest to the anthropologist in his study of the races of man, is all too recent to tell us anything of his forerunners. The remains in question, however different in detail from modern types they may appear, are quite definite and may be human.

The famous so-called "Java Man"

The case is different, however, with one piece of evidence, entirely unique, which has been brought to light and which, after much controversy and critical study by anatomists and anthropologists, is now accepted at the value put upon it by the discoverer. Near the close of the nineteenth century, of which the new theory of man's origin was the most startling and, for thought, most important achievement, a Dutch surgeon, Dr. Dubois, found in Java, in an ancient river-gravel certainly hundreds of thousands of years old, the upper part of the skull, and also a portion of the thigh bone, of a creature to which he gave the name, now celebrated, of *Pithecanthropus erectus*, the "erect ape-man." Not a trace has yet been found, in Java or elsewhere, of a second individual of this kind, but, of course, these remains suffice to prove that a species of this kind existed, and there is every reason to hope that scientific exploration in these parts may find much more than these unique remains.

The mystery that is hundreds of thousands of years old

This is the creature which has been described as the long "missing link." The creature was erect, we believe; doubtless not as erect as we are, but the evidence suggests that its hands were clear of the ground when it walked. Some anatomists have questioned whether the thigh bone, which furnishes this evidence, really belongs to the same individual as the skull, but most of them now consider that it does so belong.

The thought comes, as we study these interesting remains, that perhaps we should not call the ape-man "it," for students think that *Pithecanthropus* was a man — of sorts. He was nearer modern man than modern apes, but when his skull is compared with one of ours the differences are found to be very great. Its capacity must have been very small, compared with any human skull ever found — except for diseased skulls, such as those of certain types of idiot. The human skull contains a brain having some five or six

times the weight of that of any existing ape—in proportion to the respective body sizes. The skull of the so-called “ape-man” is definitely intermediate in this respect. It is very narrow, and has enormous eyebrow ridges. Its differences from a modern skull chiefly consist of serious defects in just the parts corresponding to those areas of the brain in which modern man differs most from the apes. The brain case is defective in its vertical diameter and in its longitudinal curvature.

The teeth of the “ape-man”

Among the remains of *Pithecanthropus* were found three teeth. A later expedition, headed by Madame Selenka, brought to light a fourth tooth. According to Professor Richard S. Lull, these teeth were of a distinctly human type. They showed no shortening of the roots or development of the pulp cavity, to which Keith has applied the term “taurodont” (ox-tooth), as found in the Heidelberg and Neandertal races. The type of teeth as found in modern man and the apes, and adapted to a more varied but less harsh diet, is designated by Keith as “cynodont” (dog-tooth). The teeth of the Java man were of this later type. The crowns were wider than long, just the reverse of the simian dimensions, and, while they show certain minor ape-like characteristics, they show certain degenerative features as well.

His brain, as indicated by his skull

But it is the quality of the brain that, above all, distinguishes man from the anthropoid apes, and the problem of man's history is the problem of his brain's history. That, above all, is where the so-called “ape-man” and the apes have their importance in our inquiry. No other creatures but ourselves have anything like our quality of brain. On this point the fiercest controversy has raged, especially around the arguments long ago adduced by Huxley. He declared that, so far as brain structure is concerned, the anthropoid apes are nearer to man than they are to the lower monkeys. In other words, the gap between the anthropoids and all

lower forms of life is greater in this most important respect than the gap between them and man. What we can infer of the brain of the “ape-man” of Java justifies us in the view that his brain was intermediate, historically, between our own and that of the ancestor of the present apes.

The study of the human brain as regards the functions of its parts

The “ape-man,” if he really was a man, can scarcely be discussed under the heading of lower animal life. Similarly, though the apes are animals, certain of their characters have had to be discussed here, as in Darwin's great book on man, because man cannot be understood without them. As regards the brain, we have much more evidence since Huxley's very notable work was done.

The work of Horsley and others upon the human brain, as regards the functions of its various parts, the localization of brain-disease—made possible by our knowing what symptoms to associate with particular brain areas—and, above all, as regards the mighty achievements of brain surgery—all these have largely depended upon the study of the brain of anthropoid apes.

The features of man's brain that are similar to those of the apes

This study was undertaken by Horsley and other workers in order to serve surgical and medical science; but while it does so, it also concerns us here, for it demonstrates in amazing and novel fashion the closeness of the relation between man's structure and that of the ape. All the main features of the human brain, even to the arrangement of its convolutions or folds, are found in the ape's brain. There is no choice but to give them the same names in both cases. And this correspondence of structure is even less remarkable than the correspondence in the functions of different areas, by which the observer of the ape, assuming the facts to correspond in the case of man, may become the beneficent surgeon of his own species.

Such are the main lines of evidence, gathered since the general anatomical resemblance of man and apes was known and detailed, which cause some present-day investigators to believe that the forerunners of man were essentially ape-like in character, and that we, the rulers of the earth today, share in the possession of a common ancestor with the apes that live wild in the forest and captive in the cage. However, as we have stated at the beginning, all this is mere speculation interpreted to suit the individual desires of the investigators.

What some present-day investigators would have us believe

Some would have it that these forerunners were not like those apes, such as the chimpanzee, which most resemble man, but rather like the gibbon, which has diverged least from the earlier forms that we find represented in the fossil records, and which also represents the nearest affinities to other monkeys and the lemurs. The presence of gibbon-like forms in the past consorts, according to them, with the other evidence in favor of their view that the forerunner of man, and of the existing apes, was a gibbon-like creature. Man's notable fear of snakes, and the anxiety of the gibbons in captivity when first they find themselves on the ground, are thus intelligibly connected; and much more, of still greater interest, may be inferred when they study in detail not merely the anatomy of the gibbon, but its habits of life and its geographical distribution. However, much has been added to our knowledge of this creature, both as regards existing forms and those of the past. At the same time, there has been some simplification of knowledge — as when it was found that forms of gibbon with gray hair and whiskers, reputed by them to be a peculiar species, were only elderly individuals of species already known.

It is the study of the gibbon especially which combines with the other lines of evidence, and by which this class of investigators reconstructs the first men for modern eyes.

The first man must have been without a rival in the world of his own day

Our ancestors were not really like that at all; and they came from Africa, or possibly from some part of Asia, presumably not so far from those southern areas in which we find gibbons and other apes — but not the gorilla — today, and in which we have found traces of what some maintain is the least human of human beings, by no means the first man, but certainly what they consider the first man on record. What, where and how the first men were, it remains for us to consider, but we shall consider to little purpose unless we keep in mind the leading facts about the possible forerunners of man. Our business is to satisfy ourselves as to what may be called man's "jumping-off" place, and if we can agree as to the kind of creature he then was, we may agree as to the kind of creature that has since explored earth and sea, and sun and stars.

No fact of limbs or muscles could explain such achievements, and we must not leave man's forerunner without looking for at least a moment at his mind.

The psychology of the ancestral ape is a subject of extraordinary interest, only to be appreciated by those who have studied the recent work of Dr. McDougall. We shall learn in due course that the intelligence is not the whole of man's mind, or where would most of us be? Far more important for conduct are our instincts and emotions — not least those which maintain the life of the individual and that of the race. Here we are beginning to find a new interest in the ape, in his curiosity, imitativeness, suggestibility, educability, sociability, and amazing parental devotion. From our present point of view, the ape's curiosity, his educability and his enterprise are of the most interest, as they show similarities to man's mind no less than the simian anatomy shows a similarity to his body. The ancestral type of man may have been mentally inferior to the least and lowliest of his present representatives, but he must have been utterly without a rival in the world of his own day.

SUN WORSHIP — THE RELIGION OF HEALTH



THE SUN WORSHIPER — BY HENRY S. TUKE, A.R.A.

We should be a very much healthier nation than we are if all our housewives knew the value of the sun. Dangerous microbes cannot flourish if exposed to direct sunlight, which is fatal to all forms of parasite life.

WISDOM AND FOLLY ABOUT HEALTH

Every Man his own Doctor; and Every
Doctor the Minister to a Mind Diseased

IS IT POSSIBLE FOR ALL TO BE HEALTHY?

HEALTH being our subject, we began in correct scientific fashion by an attempt to define and describe it. We have some idea now of what it really means to be a healthy man, and to spend twenty-four hours in a completely healthy manner. And now our business is to discover the laws and the practices whereby we may all attain this happy state.

But we must beware, or we shall fall into the error which has betrayed almost every writer on health until the present day. Notwithstanding the adage that "one man's meat is another man's poison," and the equally wise one that there can be no arguing about tastes, and notwithstanding the wise medical sayings which tell the student that he must learn to treat the patient, not the disease, since every patient differs from all others—writers on health persistently fall into the error of supposing that everything they lay down applies equally, or almost equally, to everybody. Time and experience always prove that this is not so, and doctors have long suffered in reputation because their general statements are so often found to break down when they are applied to particular people.

The time has come when this great mistake can no longer be excused. Science, which studies the laws of heredity, and the natural "make up" of individuals, has proved how widely we all vary, so that every one of us is really unique in himself or herself, and therefore has unique needs. This must be remembered by the doctor who writes upon personal hygiene; and if he remembers it, he will perform his task better than it has ever been performed

before. At every stage, whether he is discussing food or exercise or clothing or sleep, or anything else, he will try to remember, first, that in some most important things—such as having to breathe oxygen or die—we are all absolutely alike; and, second, that in many other things, very important to each of us, we are all entirely different.

Now, the wise doctor must rigorously lay down the law, if he knows it, for everybody, without exception, in the first kind of case; and he must try to describe the path of wisdom for all manner of different people—a different path for each—in the second kind of case. For instance, it is absolutely certain that we must all eat a kind of food called protein—found in such foods as meat and bread and milk and eggs—and the doctor must insist on this, and make sure that the people who follow his advice realize it, and do not try to live as if this law were not absolutely universal for every human being, as it is.

But whereas the textbooks all assert the exact quantity of protein required for health by people of such and such occupations and such and such weight, the wise doctor, who knows how individuals differ, will avoid such unscientific assertions, which look so very scientific, and will try to indicate to his readers how they can find out what is the best quantity for themselves.

There is a familiar proverb, which few people understand, though it contains wisdom useful to everybody, which says that every man is a fool or a physician at forty. If this means that anyone at forty, unless he be a fool, can play the physician to other

people, it is obvious nonsense. But it does not mean that. It does mean that every man who is not a fool should have learned about himself, say, at the age of forty — better still at thirty — so much as to make him his own best physician in ordinary matters. He ought to know what suits him, and what does not, what promotes his health and work, and what runs him down and upsets him — as no doctor on earth could possibly know. In that sense, which is enormously important, he is his own best and only physician, because he has devoted his whole life, as it were, to the observation and comprehension of a unique case, which is his own case. Plainly he must be the expert of experts — for himself.

The wise doctor studies to help people help themselves

The wise doctor who studies and endeavors to teach the laws of personal health must recognize these facts, and he must try, not to discover universal laws, which will prescribe so much sleep, so much fruit, so much reading, for everybody, because such laws would turn out to suit exactly one person and no more, but he must try to help people to help themselves, by stating those few great laws which apply to us all, since we are all human, and by then teaching us how to observe and take care of ourselves. And all the while he will beware of a very common and serious risk, which he must avoid — the risk of encouraging people to devote themselves to their own health, which inevitably succumbs, and over whose remains must run the words, "Killed by kindness."

Short lives and sad ones, or long lives and merry ones

Indeed, that proverb about fools and physicians is rather severe, for it really amounts to writing down a great majority of mankind as fools. The impartial doctor, surveying his fellows, even those who are "old enough to know better," must agree that very few of them are satisfactory, judged by his standard.

There is the frankly careless man, improvident of health, though he may be prudent and tight-fisted as regards money.

He does all manner of things which he knows, better than any doctor or any friend, are bad for him; and he continues to do them. The world is largely filled with this type of man, and woman too. Their average expectation of life is small, and their short lives are not even merry, as they know in their hearts, however brave and gay a show they may make for our eyes. The rule about lives, one need hardly say, is the opposite of the popular saying. On the whole, people have either a short life and a sad one, or a long life and a merry one.

At the other extreme is the man — and, of course, these remarks all apply equally to women — who devotes his life to prolonging it, and squanders his health in the effort to maintain it. These unhappy people read the medical papers, and they are constantly consulting doctors. They dose themselves incessantly with patent medicines, and with prescriptions which doctors have written for them, and other prescriptions which doctors have written for their similarly afflicted friends.

The man who destroys all the joy of health by imagining he is ill

They try all manner of diets and all the latest textures in underclothing; they frequently, in the course of their researches upon themselves, discover the normal and useful projections upon the back of the tongue, and suppose they have cancer; and their lives soon become a burden to themselves and to others. The present writer regards it as the most serious of his responsibilities to insure that nothing shall enter these pages which will conduce to the making of such people, and to strive to teach and suggest laws of health, and ways of obeying those laws, which do not involve all this lamentable and disastrous devotion of people's lives to their own morbid fear of illness. If one must indeed choose between this and the other kind of folly, the folly of neglect is to be preferred. Both kinds of people shorten their lives, and do themselves harm, but the health fanatics and the hypochondriacs are miserable all the time, and the careless people at least get some intervals of happiness.

Another kind of folly may be called the conscientious kind; and no writer on hygiene can be better rewarded than by the thought that he may be serving its victims. These people ignore or try to deny the existence of warnings which should be heeded, because they feel it to be their duty to go on with their work at all costs. It is a noble and not an uncommon kind of folly. Nature makes no distinction.

The price a man must pay for "burning the candle at both ends"

If a man "burns the candle at both ends" in order to get rich quickly and bully other people, or if he does so to make money for the care of an invalid wife or to bring success to some beautiful or unselfish enterprise, nature makes her award just the same. We shall carefully study this matter when we come to the questions of work and overwork and worry. They are worth careful study, because the people whom they concern are the best and bravest and most valuable people in the community, and to teach wisdom to one of them is better worth doing than to help a multitude of selfish people.

Of notable importance, also, are those who misunderstand the adage about fools and physicians, and who, having found some kind of practice which suits themselves, seek to impose it upon everybody, in defiance of the facts of human variety. These cranks have their uses, and are often able to demonstrate important facts by the experiments which they make upon themselves. Very often, indeed, their particular theory or diet suits themselves admirably, and they are wise to adhere to it.

Their folly is displayed when they forget how men differ, and seek to make every one well and strong by their own methods. Often they do great harm to their disciples, who are not suited to the particular habit or deprivation which suits the original crank so well. These remarks by no means imply that we shall merely laugh at — for instance — vegetarianism. On the contrary, we must study it most carefully, and we shall find that the vegetarians have taught us facts about diet which no one knew before.

The food that may strengthen a man one day and make him ill the next

Not only are all the candidates for health different in themselves, but each of them differs in need at different times. Health is to be attained and maintained in one way in childhood, in another in youth, and in another in old age. It is not only true that one man's meat is another man's poison, but that one and the same man may find one and the same thing meat at one time and poison at another. A man may profit by a meal one day, and be made ill for a week by a similar meal the next day, because he was eating it during an attack of intense depression or a period of fatigue, which made its digestion impossible. Plainly, circumstances alter cases.

Another important fact, constantly forgotten by amateur students of health, is what we may call adaptation. Many of us, probably all of us, are now well enough adapted to certain kinds of work, or weather, or diet, or amusement, and would suffer if they were changed. But after a time we would thrive as well, perhaps even better, under new conditions as under the old. If we examine one of the digestive juices of the pig we find that it contains one kind of digestive ferment in chief abundance when its diet is mainly made of protein. If now we alter the pig's diet, so as to make it consist mainly of starchy foods, its digestive juice alters in composition, and almost wholly consists of a ferment which deals with starch. That is simply adaptation; and all life everywhere, human, animal, or vegetable, involves adaptation, and would have little chance of survival without it.

When we are inclined to lay down the law about health in general, or our own in particular, we must remember adaptation, and be prepared to believe that there are wide limits within which we can live well enough; only that, as a rule, changes in habit, in food, clothing, exercise, sleep, and all the other questions which we are about to study, should be made gradually, so that the powers of our bodies may have time to adjust themselves to the new conditions and act accordingly.

Another most important fact, which has been forgotten by medical writers on health until very recent times, is the influence of the mind on the body. Non-medical writers have repeatedly pointed out how important is the part played by the mind. They have declared that people's minds vary, just as their faces do, and that the state of the mind affects the body, so that what is good for one man's health may be bad for another's, simply because the two people look at it in a different light. For many years past, doctors have inclined to the view that their patients are to be looked upon as simply bodies, and have heaped terms of derision and contempt upon those who attached high importance to the difference in people's minds, and to the differing states of one and the same mind at different times. Modern research has altered all that; and it must be admitted that most of this fine work has been done in the teeth of the doctors' opposition, by men they called cranks and visionaries.

The wide acceptance of a great truth which Christian Science reveals

The time for that kind of talk has passed. It is now clear to all men, doctors and patients and the general public, that the mind profoundly influences the body, as the body does the mind; and it must be realized that the attempt to deal with human beings, and especially ill human beings, as if they were merely animals, is unscientific, and leads continually and inevitably to failure.

Health, as we understand it here, is health of mind and body, and health of the relations between them. The unpalatable lessons which Christian Science has taught the doctors in recent years will not here be ignored, and we shall endeavor to utilize them for our health, and to appreciate the work of those who have shown what mighty things the mind may do for the body. The world owes a debt to Christian Science for its teaching that mind controls health, which, however, is only an expression of half the truth. Other factors have to do solely with the body and also control health.

The mistake which doctors and educationalists have constantly made

One more point of the first importance must here be stated, lest we raise false hopes. The writers on health have constantly made the same mistake as the writers on education—they have supposed that all the human material which would come under their methods would be equally capable of profiting by them. The champions of the noble and invaluable science of education have almost always assumed and tried to persuade us that their process would make us all intelligent and well informed, cultured and devoted to learning.

If, however, their hopes have been disappointed, they have declared regretfully that their methods were imperfect, that certain changes must be made, the process must be begun earlier or not so early, must be prolonged later, must be more varied or less varied, the child must have no Latin or Greek, or must postpone starting these studies until it has had three years of French, and so forth. There is no end to all this, as every student of education knows. But, even so, we do not all turn out what we should like to be; and still less do other people turn out what we should like them to be. The truth is that education can only educate what is already there to be educated.

Two essentials if we are to be perfectly healthy

In exactly the same way, and with exactly the same results, and for the same reasons, the students and champions of health, the cranks and the orthodox, the mind-healers and the drug-healers, all have promised health to those who followed their advice, and all have encountered many failures, and will continue to do so. Not only do we all differ within the limits of health, but we vary widely in our capacity for health at all, and in the degree to which we can profit by any observance of the laws of health, however faithful and vigorous. Education will not make the feeble-minded child into a normal adult; physical exercises will not

make an adult man six feet high who was only five feet six (or even five feet eleven) when he started them. And in a thousand other respects — less obvious, but no less real — our possibilities are limited and determined by what we are to begin with.

That is why it was said, in our description of the healthy man's day, that the man who would attain it must be both fortunate and wise. He may be infinitely wise; he may be the best guide of other people, and may succeed in teaching health and achieving health for thousands; he may practice what he preaches, and all the while may be bedridden from paralysis, or the victim of asthma and bronchitis, because these maladies are "in the family." To be healthy, therefore, one requires not only to be wise in practice, but fortunate "in one's choice of parents."

**Physical characteristics, health included,
largely determined at birth**

In this fundamental matter, no writer on hygiene can very well guide the reader. Any prospect of "beginning at the beginning," which is the ideal of all true science and all sound practice, is out of the question. In very large degree, the fate of each of us is sealed before birth. The main lines of the building have been laid down, and we can do no more than do our best to keep it in good repair. But no care of a ten-horse-power motor will develop it into a twenty-horse-power, nor increase the number of its cylinders, though neglect will prevent it from developing the power which it was intended to develop, and may easily decrease the number of cylinders by throwing one or more of them out of action. This analogy between the machine of steel and the machine of flesh and blood is perfect so far as it goes.

We must here abandon, therefore, all the ignorant pretensions which have been too commonly put forward by writers on health in the past, and are still put forward by the vendors of special means for obtaining health. There is no certain recipe for health for all. If the reader's body or mind be like a ten-horse-power motor, we aim at the very useful object of enabling him to develop his full power, and to retain

it for as many years as possible. Not only do we regard it as futile to aim at making him the equivalent of a sixty-horse-power engine, but we know that such efforts would do him serious harm. Any machine overtaxed, asked to do what is beyond its natural capacity, will soon cease to be capable even of that. Men with little hearts, perfectly satisfactory under proper conditions, seek to develop into champions of strength and endurance. They undergo special training, they climb mountains, run long distances; and after a short time the heart, instead of growing stronger, stretches and dilates, and they may be maimed for life. It is the case of the frog who sought to emulate the bull, and was rent in pieces by its own efforts at expansion. It might have made an admirable and perfect frog, if it had left well enough alone.

In this course of study, therefore, we definitely promise less to the reader than he will find promised or implied elsewhere. Follow he never so wisely the advice we tender, there are limits — narrow in some directions, broader in others — which he will never be able to transcend.

**The rare feat of making the most of a
man for the longest possible time**

No advice that we can offer here, nor even any advice which future knowledge can offer, will alter the number of vertebrae in his backbone, or the color of his eyes, or a thousand other facts of his constitution — visible and invisible, facts of structure and of function, of brawn and of brain — which are the beginning of him. He and we come in with our efforts when the beginning, and many stages later than the beginning, have been accomplished, for good and for evil.

Yet we also may promise more to the reader than these warnings may suggest — much more than he now expects, just because we promise so much less. Though nothing can alter his natural heritage, and though in some respects that is at least as important as anything which it is in his power to effect, yet, just because we recognize his limitations, he and we may in concert achieve the very rare feat indeed of making the most of him, and making the longest of him.

It is a feat so rare that, in strict judgment, we may, perhaps, say that it has never been accomplished. It is doubtful whether any man or woman, since time began, has ever achieved the utmost in the way of health and longevity which was possible for their native endowment. But, even if we ask for less than the utmost, we may be sure that not one in a thousand of mankind at the present time really enjoys the measure of health and longevity which is possible for him; and the contrasts between different people in their proportion of the possible that they achieve are enormous, quite apart from the fact that the measure of the possible varies in everybody.

The candidates for health and the problems they bring to the doctor

On all hands the doctor sees these contrasts, ranging from the man of magnificent natural health and physique, who ruins all in a year or two of folly, to the delicate youngster, already stricken with consumption, who makes a brave and wise fight — in matters of health bravery is no use without wisdom — and lives a long, useful, and happy life, crippled, perhaps, a hunchback perhaps, but a fine fellow nevertheless, in the finest sense of the word.

Many of his patients he can do little with, short of having them born again and

different. Others have sufficient qualities of body and character to enable them to be almost independent of him, for they will soon learn, and put into practice, more wisdom about themselves than he can possibly attain. But he must do his best for all of them in the circumstances, and that may most surely be done by beginning, not at the beginning, for that is impossible, but at the few all-important points where health makes identical demands for all, and exacts similar penalties. The first of these is the question of the air we breathe and the manner of breathing it, and these we shall begin in our next chapter.

The victory that is higher than the conquest of a city

Meanwhile, the facts of heredity are not to be looked upon as wholly uncontrollable. On the contrary, to recognize one's limitations and peculiarities and special needs is half the battle of wisdom in matters of health and of conduct. Heredity and its laws are of profound interest, not only from the standpoint of Life — the group in which they are discussed in this work — but also, as the wise reader will discover, they are of personal and selfish interest to us all, helping each of us to understand and thus to rule his own spirit, a feat which the wise king ranked higher than the conquest of a city.



Courtesy of General Electric Co.

TADPOLES SHOWING GROWTH OF INTESTINES

INGERSOLL WATCH

Looking through solid objects with X-rays produced by electricity.

MAGNIFYING OUR SENSES

How Man is Reaching out Beyond his Senses, and
is Blotting out "Impossible" from the Dictionary

AMAZING JOURNEYS IN AN INVISIBLE WORLD

THERE have been two or three periods in the history of the human race when it seemed as if man were about to penetrate into the secrets of nature. His intellectual power developed in a magnificent way, and his mind went voyaging on strange seas of thought in the illimitable spaces of the universe.

Always, however, man arrived at little more than a few interesting but unverifiable guesses. He was defeated by the limitation of his senses. His intellect was a marvelous instrument, which was prevented from working thoroughly and efficiently because its avenues of knowledge were amazingly imperfect. His eyesight, his senses of hearing, and of touch, taste and smell were greatly inferior to those of certain birds, insects and animals; he lacked, too, their special instincts to find their way across unknown tracts of country. With these imperfect senses he stumbled about the world, like an almost sightless beggar lost in a wild, unexplored country at night, and carrying a feeble lantern which threw a dim circle of light a few yards before him.

Lifting his eyes to the heavens, he could see only one or two thousand little points of light. Had he studied the sky in especially favorable circumstances, he might have been able to discern about two thousand stars. Yet the starlight that fell around him came from a hundred million blazing suns. When the day broke, and he looked down at his feet, he could only trace a few small forms of life; yet in the least piece of earth there were myriads of living shapes; and his own body contained millions of minute organisms. Col-

ors that he could not see and sounds that he could not hear were all about him. The ground on which he trod vibrated under the impact of billows falling on a shore hundreds of miles away, and trembled with the waves set up by an earthquake which occurred, perhaps, a hundred years before at a distance of thousands of miles.

Every form of matter around him — the pebble he stumbled against, the stone of which he built his house, the metal he fashioned into tools — emitted subtle streams of electric energy. Yet, blind, deaf and numbed to all this, man wandered about the earth, fancying that by mere guesswork he could come to understand and control the mysterious processes of nature. But, before he could obtain any large and certain knowledge, he had to invent some thousands of exquisite mechanisms which would serve, in a way, as new and far-reaching senses.

Most of this marvelous extension of the senses of man has been won during the last fifty years; and the beginning of it only goes back to the age of Shakespeare. "What a piece of work is man!" said the great Elizabethan. "How noble in reason! how infinite in faculty! In action, how like an angel! In apprehension, how like a god! The beauty of the world! The paragon of animals!" Yet in what a narrow world Shakespeare lived — a little plot of earth, lighted with two revolving lamps, and covered with a blue roof, inlaid at night-time with bright spangles of light! The only things the Elizabethans found difficult to explain were the wandering stars — by which they meant the planets — and the comets.

When we contrast this quaint picture of the world with the universe of our days, and especially with our certain knowledge of this universe, we can get some idea of the enormous and sudden development of the senses of mankind in the last three hundred years. What a multitude of great men — greater than Columbus — have recently extended the boundaries of human knowledge! Not only have they opened up a strange, illimitable world above our heads, but they have discovered a more wonderful tract in the ground on which we thoughtlessly tread. Overhead is the infinitely great; beneath us and around us is the infinitely little. And it has all become visible — visible to our senses — that is the almost supernatural marvel of it. Here, on the one hand, are the astronomers asking us to look at their spectroscopes, and see with our own eyes the elements of which some star, millions on millions of miles away, is composed. Here, on the other hand, are the microscopists wanting to reveal to us the mystery of matter. They do not want us to believe anything: they, too, ask us to see. Look! These are the corpuscles of which an atom is built. The electric and magnetic currents are sending them in a stream against this screen. We can measure them — their velocity, and their mass, and the charge of electricity they carry. We cannot remember the figures? Well, here is a photograph of the thing we have seen. Let us make our calculations from it.

More separate lives in a drop of water than human lives on the earth

We can study at leisure the photographs taken during the experiments. If we have a head for figures, here is the conclusion at which we arrive: in a single drop of water there are far more separate entities than there are human entities upon the earth — say about 2,000,000,000,000,000,000,000 molecules! These molecules are divisible into even smaller parts, which are called atoms. A little while ago an atom was not a thing, but only a theory; it was merely argued that matter might consist of atoms before it was made up into different elements.

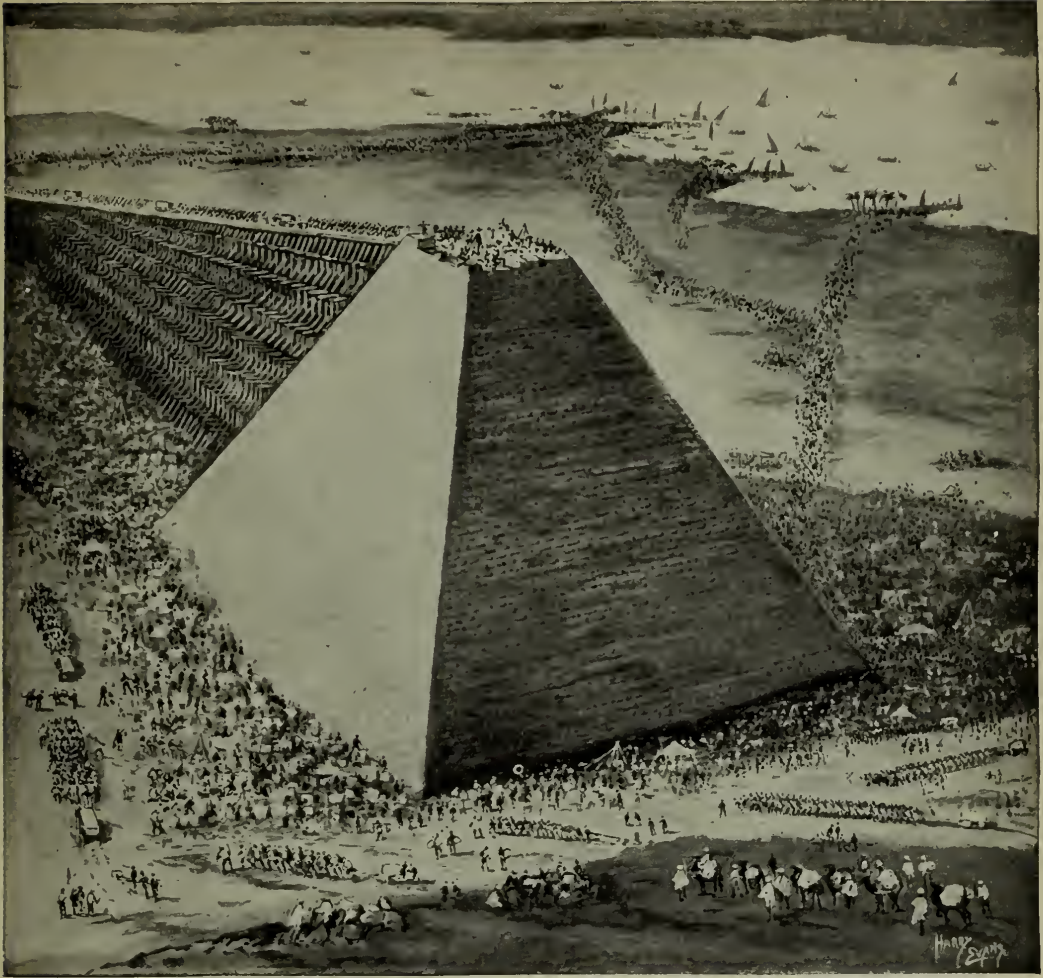
Well, let us suppose that an atom could be magnified into the size of a large room — an utterly impossible feat, for the atom is much smaller than the smallest wave of light, and no microscope, therefore, could define it. Still, let us suppose that an atom could be thus magnified: then the corpuscles of which they are composed would appear like specks of dust in the large room. Yet now the mass and velocity of these corpuscles can be measured!

A little over three hundred years ago, the vision of the keenest-sighted human being was inferior to that of an eagle. Now man has broken up the atom, and he has seen it breaking up. Turning from the study of the heavens, he picks up a fragment of earth beneath his feet, analyzes it into parts more numerous than all the millions of stars in the sky, and then discovers that each of these parts is an arrangement of forces as wonderful as the arrangement of the solar system.

Man may hear today the earth tremors which Napoleon might have heard

All this new science is founded on observation and experiment; that is to say, it is founded on the evidence of the senses. But these senses are newly acquired faculties. As by the stroke of a magician's wand, the almost sightless beggar lost at nightfall on an unexplored moor has swiftly been transformed into a giant. His actual voice resounds over an entire continent; with the speed of lightning he sends a message round the world; his vision penetrates into the fiery core of the remotest star of heaven; he can feel the heat of a candle burning over a mile away; he can discern the infinitesimal microbe; and he can weigh the earth on which he stands. Putting his ear to the ground, he listens to the beat of the surf on some far-off shore, and hears today the echoing rumble of some terrible earthquake that happened in the days of Napoleon; then perhaps he feels a new movement in the earth, and in a few minutes he has traced it to its source, maybe in some Asian desert. Such is the infinite delicacy of perception which is combined with the extraordinary power and range of the new senses of man.

MAN'S POWER IN TWO CIVILIZATIONS



THE BUILDING OF THE GREAT PYRAMID BY MEN MASSED TOGETHER LIKE ANTS



A MIGHTY CRANE WHICH DOES THE WORK OF HUNDREDS OF MEN

In ancient civilizations men worked like ants together, enslaved in tens of thousands. A hundred thousand slaves are said to have built the Great Pyramid. The despotism which massed men like ants has passed away, and in the modern world the power of thousands of men is put into a single machine.

The power within man's grasp for thousands of years

By a curious piece of irony, it was when man was losing some of the small natural power of his eyesight that he first attempted to extend his senses.

In the ruins of the palace of Nimrud at Nineveh has been found the earliest-known form of magnifying-glass. It is a convex lens of rock crystal, four inches long, and nearly one and a half inches across. For thousands of years man made no use of this wonderful invention, except to increase his power of vision when it was failing through old age or natural shortsightedness, or when he needed a finer definition in gem-cutting. Even when, in the thirteenth

century, Roger Bacon worked out the principles of both the telescope and the microscope, nobody took the slightest notice of his discovery. And it was not until about the beginning of the seventeenth century that some spectacle-makers in Holland were moved by a stronger and larger passion of inquiry. The spirit of modern science had just been born, and the Jansens of Middelburg were affected by it. Instead of keeping to spectacle-making, they began experimenting with the lenses they were polishing; in 1598 they invented the modern microscope, and in 1608, Lippershey, another optician of the same town, constructed a telescope. A year later Galileo was sweeping the skies with the new invention at Padua and finding the satellites of the planet Jupiter.

With the improvement of optical flint glass, which commenced in 1754, and the invention by John Dolland of the achromatic object lens (1758), better telescopes were made possible, but not until quite late in the nineteenth century were many

constructed with object lenses greater than 12 inches in diameter. In the old days telescopes were built with an extraordinary length of tube. Better effects are now obtained by increasing the breadth of the instrument. The simple instrument

that Galileo used has now been elaborated into an enormous and intricate thing.

The largest refracting telescopes in the world are in the United States. The one at Yerkes Observatory, Lake Geneva, Wis., has an object lens 40 inches in diameter, with a focal length of 64 feet. The movable part of the instrument turning on the polar axis weighs about 12 tons, and the clock 1½ tons. Other large telescopes are the 36-inch at Lick Observatory, Mt. Hamilton, Cal., where many

important astronomical discoveries have been made; the 26-inch at the U. S. Observatory, Washington, D. C.; and the 24-inch (photographic objective) belonging to Harvard University. There is a 30-inch refracting telescope at the Allegheny Observatory, Riverview Park, Pa.

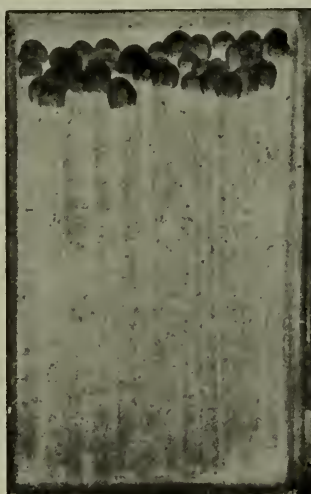
Two of the most perfect reflecting telescope instruments ever built are at Mt. Wilson Observatory, Pasadena, Cal. One mirror is silver on glass, 60 inches in diameter, and weighs nearly a ton. At the same observatory is a 100-inch reflector; the tube with the mirror at the bottom is 43 feet long, and with the mountings weighs nearly 20 tons. There is a 36-inch reflector at Lick Observatory, Harvard University has a 28-inch and a 60-inch, and at the Yerkes Observatory is a 24-inch.

The difficulties of casting tremendous glass discs, and of obviating the distortions produced by changes of temperature, are very great; and very great, also, is the difficulty of providing mountings to carry the huge lenses with the necessary



WHAT NO EYE CAN SEE

The left photograph is of a microscopic slide as it appears to the eye; on the right is a photograph of a portion of the slide taken with a microscope, showing a host of living bacteria.

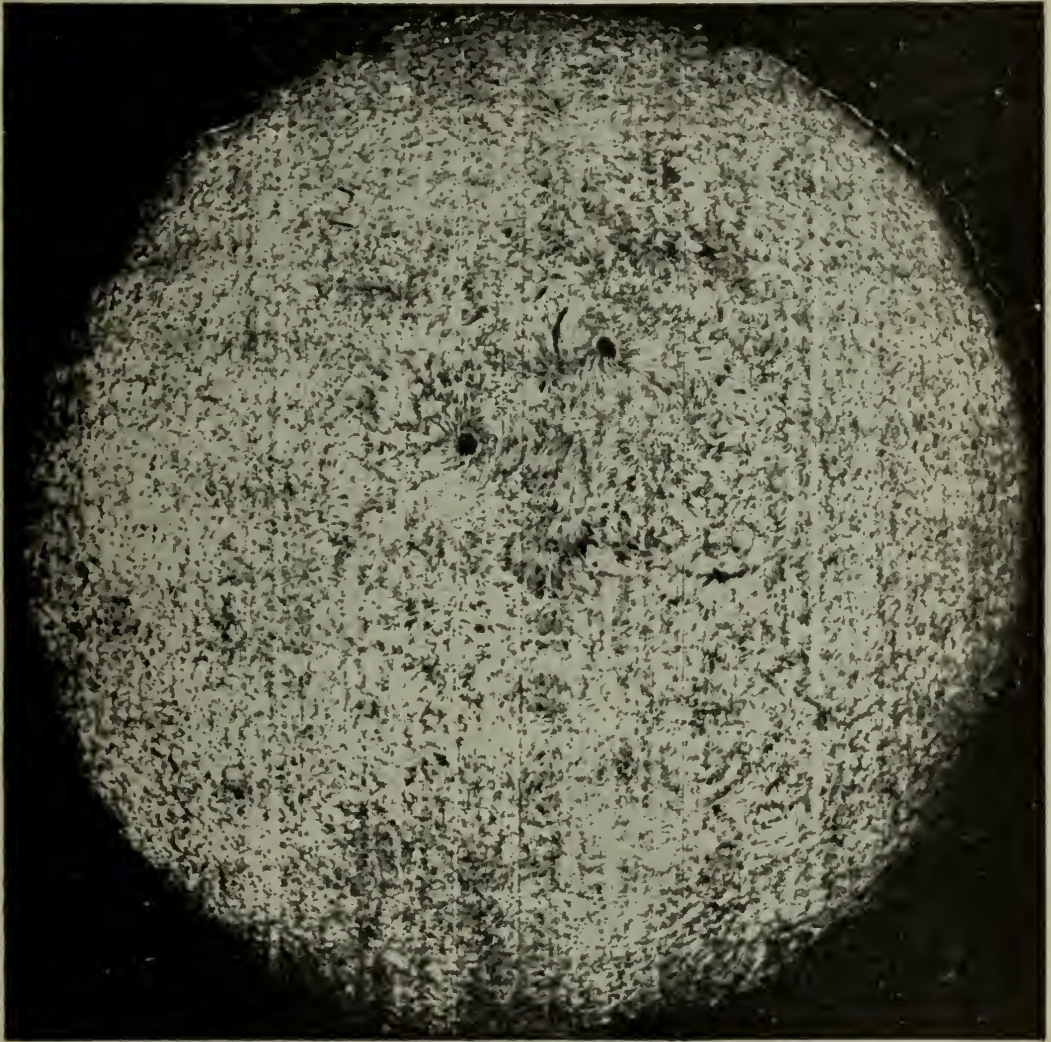


MATCHES PHOTOGRAPHED THROUGH THE BOX BY X-RAYS

precision. With each new improvement in manufacture, however, the size of the modern telescope increases. Yet this in itself would not greatly add to our knowledge of the elements of the stars. The larger the telescope, the smaller the stars appear. This, of course, is not true of the

more minute and point-like as the power of the telescope increases. Their apparent discs appear large in small telescopes, and small in large instruments.

It was not, therefore, by means of any telescope that man found out what the stars were made of. Neither was it by



A PHOTOGRAPH OF THE SUN SHOWING SOME OF THE STUFF IT IS MADE OF

Taken at Mount Wilson Observatory, California, by Professor Hale. By a marvelous adjustment of instruments, the telescopic camera was made to "see into the sun," as it were. What we see in this photograph, technically called a "spectro-heliogram," is really a mass of clouds of calcium vapor, which are invisible to the eye, even through the best telescope. The dark patches are sun-spots.

sun, the moon, or the planets. With each increase in the diameter of a telescope, the structure of these heavenly bodies can be studied in more detail. The stars, however, are so inconceivably remote that no telescope can reveal their shape. They are mere flicks of light which show

means of the telescope that Sir Norman Lockyer discovered in 1868 in the sun the new element of helium, which Sir William Ramsay found again in 1895 in cleveite, a Norwegian mineral, and afterwards in the mysterious substance of radium.

This marvelous achievement ranks among the greatest triumphs of modern astronomy. Nothing is so calculated to display the almost supernatural extension of the senses of man as the fact that he is able to trace a new element in the flaming sun twenty-seven years before he chances to find it on the earth. All this was the indirect result of an experiment which was announced in 1672 by Sir Isaac Newton, sixty-three years after Galileo first swept the heavens with a telescope. Newton admitted a thin ray of sunlight through a narrow slit into a dark room, so that the light fell upon a piece of three-sided glass. The prism of glass split up the white ray and reflected it in a band of rainbow colors. As it is well known, whiteness is composed of a mixture of all colors. These colors represent the various lengths of waves in which light travels in its passage through the ether. Red waves, for instance, are about 1-39,000th of an inch long, while violet waves are about 1-60,000th of an inch long. In passing through the prism of glass, these waves are sorted out into a rainbow band, or spectrum. An ordinary rainbow is formed in somewhat the same way by sunlight falling on raindrops.

By taking the rainbow out of the skies and placing it in the laboratories of science, Newton gave mankind an instrument more wonderful than the telescope. By means of it man is now able to penetrate into the flaming mass of a star, billions of miles away, and discover what it is made of.

This is surely the longest and most wonderful flight of the human mind. Yet the means by which it is done are very simple. A German man of science, G. R. Kirchhoff, discovered them about the middle of the nineteenth century. He used a lantern throwing out a ray of limelight; this ray was broken up on a prism and thrown on the wall in a band of color. Kirchhoff placed a lighted lamp before the ray from the lantern, and put a little salt into the flame of the lamp. Now, salt burns with a yellow light; and Kirchhoff expected that, on mixing this yellow light with the white ray from the lantern, he would deepen the yellow part of the spectrum.

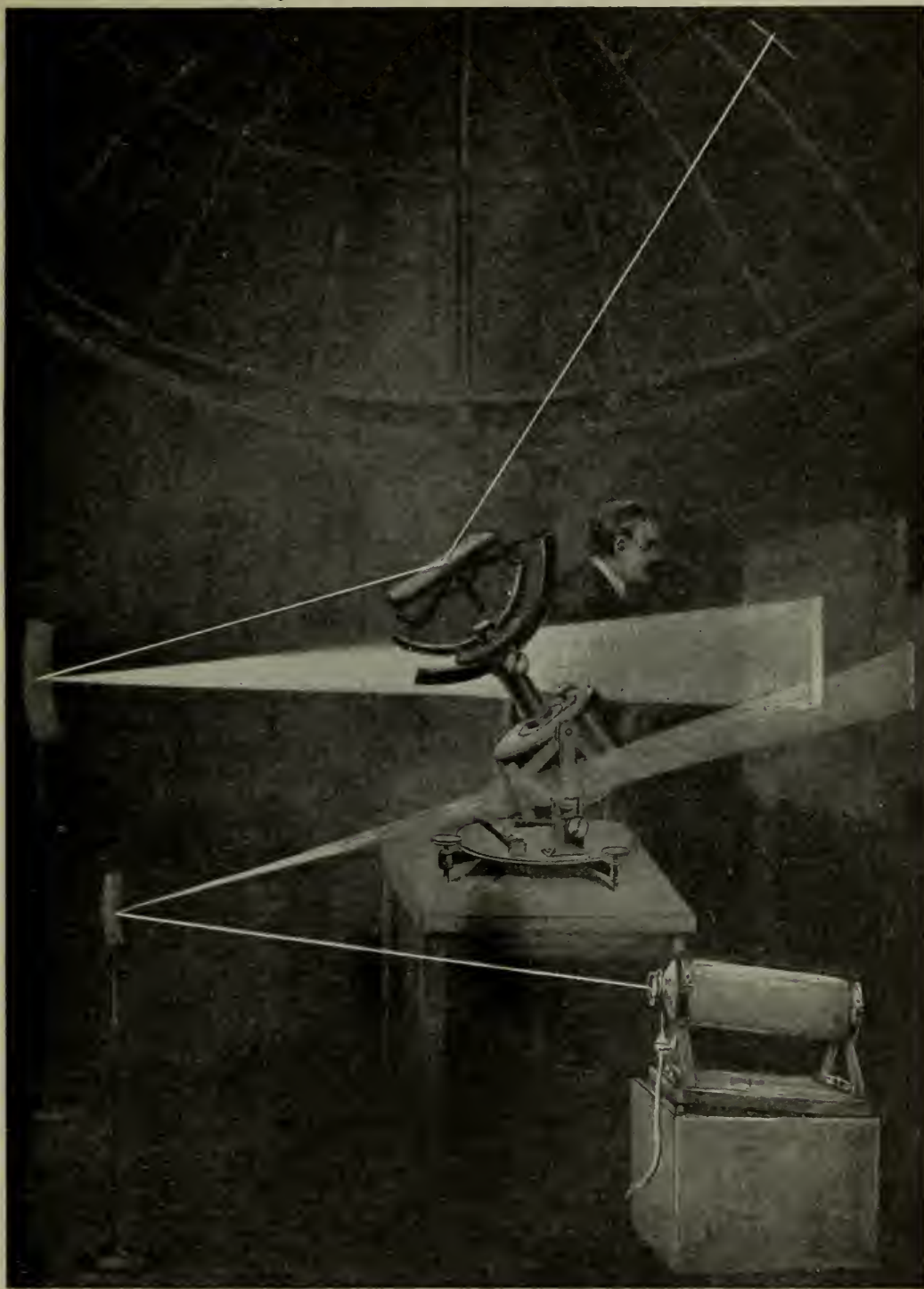
But, to his surprise, he saw a dark line start out where the yellow line should have come. A curious thing had occurred. The light from the lantern was hot, and the light of the lamp in which the salt was burned was much cooler. When the yellow waves from the lantern reached the yellow waves in the lamp, they expended all their energy in heating up to their own temperature the waves coming from the burning salt. The first yellow waves were absorbed on their journey; so there was a blank space in that part of the spectrum where they should have been.

The wonderful map that men have made of the light of the sun

This is what happens in our sun and in every star. At the center is a mass burning at an extraordinary heat. From this burning mass arise enormous clouds of flaming vapor. These clouds, however, are cooler than the central heart of fire. So every hot wave of light from the elements flaming in the furnace is absorbed by the corresponding but cooler wave coming from the vapor. That is why the spectrum of the sun or a star is composed of a band of colors streaked with dark lines. Nearly all these lines have now been mapped out according to the elements which they represent. By letting the light of a certain star fall on the spectroscopic, the astronomer is able to tell from the colors and lines exactly what the star is made of.

A chemist analyzes substances in the same way. In 1895 Sir William Ramsay was analyzing the mineral cleveite. He burned it in a very hot furnace and turned it into gas, and examined this gas through a spectroscopic. He found that it gave a yellow line in that part of the spectrum which is called "D₃," near the yellow lines made by the ray from burning salt with which Kirchhoff had experimented. Now, this D₃ yellow line had been discovered by Sir Norman Lockyer in 1868 while examining the highest and most vaporous prominences of the sun. Thus by means of the spectrum the marvelous double discovery of helium was made, and it has again been found by recent spectroscopic study in the emanation of radium.

FINDING OUT JUST WHAT A STAR IS MADE OF



As a star travels across the sky, its ray is caught on a glass plate by a machine moved by clockwork, so as to keep in the track of the heavenly body. From the glass plate the ray is reflected on to a spectroscope — a concave piece of bronze. This is ruled with fine lines, which break the ray of light into a band of colors, and this band is called a "spectrum." The spectroscope throws the colors on a screen, so that they may be easily studied. The astronomer often burns some known substance in a retort, and throws its spectrum also on the screen, as shown here, to compare it with the analysis of the star.

The astonishing power of the spectro-scope, which breaks up light

The modern spectroscope is perhaps the most wonderful instrument of modern science, in regard both to its power and to the skill necessary in making it. The prism of glass is no longer used for the most delicate investigations. Its place is taken by a simple-looking piece of bronze, with an apparently slightly rough surface. That slightly rough surface represents the very highest reach of human ingenuity and mechanical skill. It is formed of lines ruled by the finest point that can be put on a diamond. If during the operation the point of the diamond is in the least way worn, the piece of bronze is useless. The lines must be accurately spaced, and ruled from fifteen thousand to twenty thousand to the inch! The work is done by a machine invented by Professor H. A. Rowland, and placed in a constant temperature in an underground vault in the Johns Hopkins University.

The screw, which moves the plate forward by 1-15,000th of an inch between the strokes of the diamond, contains almost no errors; and the effect of the exceedingly minute irregularities is compensated by ingenious devices that form part of the ruling-engine.

The tremendous band of light which our eyes cannot see

The machine is automatic in its action. When it is set in motion the ruling of a large spectroscope goes on without interruption for six days and nights. By ruling the lines on a concave piece of bronze, the spectroscope is made so that it acts without any telescope. The ray of light falls through a slot in the roof of the observatory directly on the concave piece of bronze, and a spectrum is formed which can be examined by the eye, or photographed for further study.

The spectroscope is especially interesting for its strange revelation of the gross defects of the human eye. The telescope and the microscope flatter us; they merely prolong and magnify our actual power of vision. By means of them, we only add more lenses to the lenses of our eyes, and so increase our natural sight. The spectrum produced by the spectroscope teaches us, however, that we are almost sightless. On either side of the small fragment of colors which the human eye discerns in the spectrum, stretch long bands of invisible hues. Some of these represent waves of light too long for us to see; others are produced by waves too short to make any effect upon our eyes. Only an exceedingly small part of light is translated by us into vision. Beyond the real rays of the rainbow-like spectrum, extends an unseen color, called "ultra-red." Its existence was not



THE LIGHT BY WHICH WE SEE THE WORLD

Our eyes look out upon the world by means of waves of light from the sun, but see those of only a certain length. Others are invisible to us, though we know of them and can photograph by them or even measure them. This black block represents all the light-rays that we *know* to exist, and the thin white line the light by which we see.

discovered until 1800, when Sir William Herschel held a thermometer there. Beyond the violet end of the spectrum is another invisible kind of

ray — the ultra-violet ray — which J. W. Ritter found in 1801, by placing a sort of photographic paper at the lower end.

If the evolution of the physical powers of man is not at an end, there might possibly be evolved a race who would be able to see by means of the ultra-red rays of light. To such a race ordinary sunlight would be as useful as it is to us; for there are all kinds of rays in the sunshine. But the new race would also be able to sit in an absolutely dark room, warmed by hot-water pipes, and see and read there as well as we can do by gas-light. Their windows might be made of thin plates of hard rubber, and yet let the light through to them; and they could study the sun with telescopes fitted with lenses of the same hard, dark material. Perhaps creatures may exist somewhere in the universe with the strange power of seeing only with the ultra-red rays that remain

invisible to us. If, however, such creatures are to be found, they are likely to possess certain disadvantages of vision. What these disadvantages are, science is able to show us by actual experiment. By employing a screen which admits only ultra-red rays into a camera, and by preparing a special photographic plate, it is now possible to obtain a picture of the world as it would appear to creatures who see only with the long waves of the invisible red rays of light. In an ultra-red photograph the blue daylight sky appears as black as night, and the trees show white, as though the foliage were dusted with snow. This inversion of natural color is due to

they had found the philosopher's stone, for these rays will turn one kind of phosphorus into quite a different kind; they will produce violent explosions; and make some substances give out light without producing any heat. They also have some wonderful healing properties. Certain cancerous growths disappear under their influence, and so do various skin diseases. It is the invisible violet ray which works in the green leaves of plants, and turns carbonic acid and water into sugars and starches. As this is the first step towards the organization of life, it will be seen that the subtle action of the wonderful unseen violet ray is of tremendous importance to us.



THE MAN WITHOUT A SHADOW — A CHARACTER IN FICTION MADE TRUE BY SCIENCE

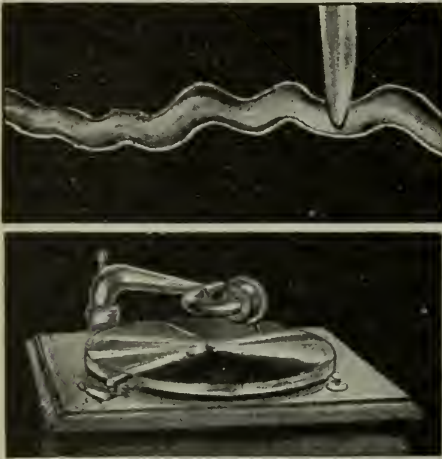
A famous story of the last century by Adelbert von Chamisso, called "Peter Schlemihl," had for its central character a man who sold his shadow. These two photographs, taken practically at the same moment, show the shadowless man in fact, though no eye has ever seen him. The second picture was taken by means of ultra-violet rays of light, invisible to the eye, which passed through the shadow,

the fact that the blue and violet waves of light are excluded by the ultra-red screen.

In an ordinary good photograph, little or none of the light that we see is used in printing the image of natural objects. Here the other invisible end of the spectrum — the ultra-violet ray end — comes into play. By means of a screen of quartz, one can cut off all visible light from a camera, and exclude the ultra-red rays as well, and still take photographs as usual. The invisible world of the ultra-violet ray has been explored by means of the delicate salts used in photography. Ultra-violet rays possess some extraordinary powers. Had they been known three or four centuries ago, the alchemists would have fancied

The ultra-violet rays shine through many substances impervious to visible light. Thus, if creatures existed with eyes attuned to these short waves of light, they might also live in rooms as black as ink to us. Perhaps it might be thought that, though these two invisible worlds of light may exist, man does not lose much by being excluded from them. Well, let us make a few calculations. Men of science have taken the unit of microscopic measurements to be the millionth of a millimeter — a millimeter being equal to about 1-25th of an inch. The wave-length of the longest known ultra-red ray is, according to Professor S. P. Langley, 1-16,500th of an inch; the shortest known ultra-violet ray

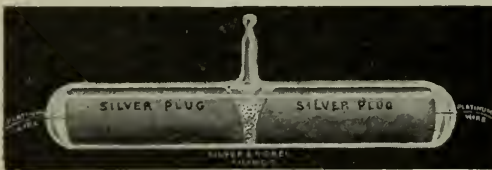
is 1-32,500,000th of an inch. Our eyes, however, cannot perceive a wave of light longer than 1-32,600th of an inch, or shorter than 1-62,850th of an inch. Our sense of light is the chief and most highly developed of our senses; it is the main avenue of knowledge to our intellect, yet it is terribly defective.



IMMORTALIZING THE HUMAN VOICE

The top picture shows a gramophone needle, much magnified, traveling in the grooves made by vibrations of air produced by the human voice. It follows the lines on the revolving disc, creating sound-waves exactly similar, and thus reproducing the voice.

But, after all, the mind of man is at last able to fashion instruments by which it can penetrate into the invisible worlds around it. By means of the microscope new forms of infinitesimal life are now being constantly discovered. The first microbe



THE LITTLE INSTRUMENT WHICH MADE WIRELESS TELEGRAPHY POSSIBLE

We send a radio message by means of faint rays in the ether — so faint that at one time science knew no means of “picking them up.” Then the “coherer” was invented, the instrument here shown, a tiny glass tube, in which are two silver plugs. Between the plugs is a space where lie loose grains of nickel and silver. It is these filings which “pick up” the waves and cohere, so completing a circuit and making the transmission of radio messages possible. Much more sensitive detectors have since been devised.

was seen by a Dutchman, A. van Leeuwenhoek, in the seventeenth century, but not until Pasteur’s time was the study of the minutest of organisms conducted in a scientific manner. Strange as it may seem, the microscope is not, in spite of its wonderful power, the chief instrument in the discovery and study of the disease-producing microbe.

The armies of death which no microscope can reveal

Many of these invisible armies of death cannot be seen under the most perfect of modern microscopes. The limits of visibility with the microscope have been very carefully measured, and they are found to range from a hundred-thousandth to about two hundred-thousandths of an inch.

As under this magnification the outline grows very dim, many comparatively visible objects cannot be distinguished. In these circumstances, it is necessary to invent some color which will stain the microbe with a color different from the hue of its surroundings. This could not be done until the dyes made from coal-tar were carefully examined; and even at the present day there are many disease-producing microbes which are well known from their effects, but which cannot be stained and made visible. Some of them are fairly large, for they do not get through a filter; yet, until some means of staining them is discovered, they cannot be studied with a view to protecting mankind from their attack.

In regard to its extraordinary, fine power of measurement, the interferometer is far more important than the best microscope. By means of the interferometer an observer is able to detect a movement through one-five-millionth of an inch! The principle



on which Professor Michelson of the University of Chicago constructed this instrument is very simple. The machine uses the minute lengths of waves of light. If two pebbles are dropped in a pond, say a yard apart, two systems of waves ripple out in circles. When the waves from the two systems meet, a varying effect is produced. If the crests of one set of ripples coincide with the

depressions from the other set, the water in that particular spot becomes smooth. The waves, then, interfere, and one set destroys the other. If, on the other hand, the crests of waves from the two sources coincide, the crests rise to twice their original height. The interferometer uses light-waves sent out from two points, like the ripples produced by dropping two pebbles in the pond. The two sets of light-waves either interfere and produce darkness, or unite and produce light of double brilliancy. These alternate bright and dark bands are called "interference fringes."

How men measure a five-millionth part of an inch

Such is the theory. Now let us attempt to explain how it is worked out in practice. A beam of light falls on a lens which makes all its rays approximately parallel. The beam is then directed on to plate glass; the plate glass divides it into two beams. Each beam is reflected on to a separate mirror; each mirror, again, reflects its beam in such a way that the two beams meet, like the two sets of ripples in the pond. The waves of light then either interfere or coincide; they produce either darkness or more brilliancy; and the effect is easily observed through a tube. Every part of the instrument is exquisitely finished and adjusted, and responds to infinitely delicate alterations. The heat of a hand near one of the beams makes a new pattern in the interferences; a lighted match creates a wild storm among the minute waves of light.

The way in which the earth was weighed by an ingenious method

By means of this marvelous instrument Professor Michelson has made a notable experiment in determining the force of gravitation. He measured the amount of attraction which a sphere of lead, eight inches in diameter, exerted on a small ball hung on the arm of a delicate balance. The force to be measured was 1-20,000,000th of the weight of this small ball, and it produced in the interferometer a displacement of seven fringes of the light-waves.

Professor Michelson could easily weigh the earth by means of his wonderful little invention, but this had already been done by Professor J. H. Poynting, of Birmingham, by another very ingenious method. We cannot weigh the earth in the ordinary way; we cannot apply to it our ordinary measurements of weight. Our tons and pounds are only measures of the force of gravitation which the mass of the earth exerts on objects on its surface. The earth cannot pull itself to itself, and thus, in the everyday sense of the term, our planet



A PHOTOGRAPH TAKEN BY INVISIBLE LIGHT

There are three kinds of light that we know — the light by which we see, ultra-violet light, and infra-red light. The difference is in the length of the light-waves, the eye being able to use only waves of certain lengths. This photograph was taken in a quarry in Syracuse, Sicily, by means of infra-red light-waves, which are too long for the eye to see.

has no weight at all. Moreover, though we can estimate the size of the earth, we cannot say how much of it is heavy substance and how much is light. We do not know, in short, how dense it is, but — and here is the miracle — we can find out this. For it is now possible to measure what all the heavy rocks and lighter elements *weigh in the mass* — that is to say, we can find out their general density, when they are contrasted with a globe of the same size composed of water.

The pull on a spring balance by a force
4000 miles away

We know a cubic foot of water weighs about $62\frac{1}{2}$ pounds. If we knew what a cubic foot of the general mass of earth weighed compared with the density of water, we could calculate the weight of a globe 7912 miles in diameter.

Thus the process of weighing the earth consists in finding its mean density; and water, which is said to have a density of one, is taken as a standard substance. Professor Poynting discovered that the density of the earth was about 5.4934.

And this is how he did it. He hung two leaden weights, weighing fifty pounds each, at the end of a large spring balance a few feet above the earth. The pull of the earth was then fifty pounds; and it was exerting this pull with its center about four thousand miles, or twenty million feet, away. Under the balance where the two weights hung, Professor Poynting placed a heavy mass of lead weighing about three hundred and fifty pounds. It was set on a turntable, so that it could be moved from one fifty-pound balance weight to the other fifty-pound balance weight. The three hundred and fifty pounds of lead rested one foot away from the first fifty-pound weight, and by gravitation that weight was attracted to it.

How we know that the earth weighs
six billion trillion tons

To the fifty-pounds pull which the vast mass of the earth exerted on the fifty-pound weight, there was now added an infinitesimal additional weight created by the gravitation pull of the mass of lead on the turn-table. The fifty-pound weight, in short, now weighed about 1-250th of a grain more. Figuring all this out, it appeared that the pull of a 350-pound weight, at the distance of a foot, was equal to 1-250th of a grain, or 1-1,750,000th of a pound—that is to say, the pull of the earth at a distance of twenty million feet was about a hundred million times as great as that of a sphere of 350 pounds at one foot. If the earth could be placed at an average distance of one

foot from the fifty-pound weight, instead of at a distance of twenty million feet, its pull would be proportionately greater—about four hundred trillion times greater; so that at equal distances the pull of the earth would be *four hundred trillion times* that of a hundred million 350-pound spheres. But, as already explained, at equal distances these pulls are proportional to the masses concerned, and thus, by doing a little more arithmetic, it has been found that the earth weighs about 12,500,000,000,000,000,000,000 pounds, or about six billion trillion tons. A billion is here reckoned as a thousand millions, a trillion as a million millions.

In the actual experiment the balance was placed in the cellar, and a mirror was connected with the balance pointer. This mirror was so arranged as to magnify a hundred and fifty times the movement of the balance beam. Through a small hole in the ceiling of the cellar a telescope was fixed and in the room above Professor Poynting watched the balance through the telescope. So delicate was the apparatus that if any one walked about the house Professor Poynting was unable to carry on his work. The step caused the mirror to quiver, and interfered with the reflection of a scale which was studied by means of the telescope.

One boy's weight which might upset the
weight of all France

This difficulty was overcome by placing the instrument on great blocks of india-rubber, and the balance then worked well for a year, but it began to go wrong, owing to the floor of the cellar tilting whenever Professor Poynting moved the 350 pounds of lead from one side of the balance to the other. The tilt was so slight that, had the floor been ten miles long, one end of it would have been raised only one inch higher than the other end ten miles distant, yet this minute disturbance seriously affected the professor's observations. Gradually all difficulties were overcome, and he calculated the density of the earth to be 5.4934, compared with the density of water as one.

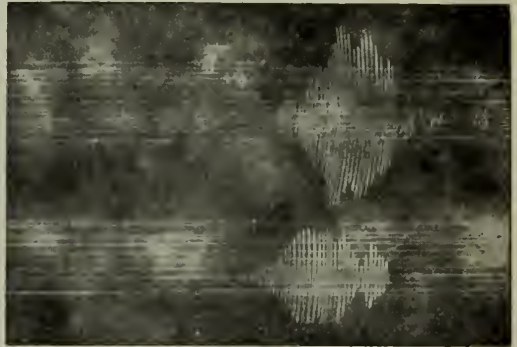
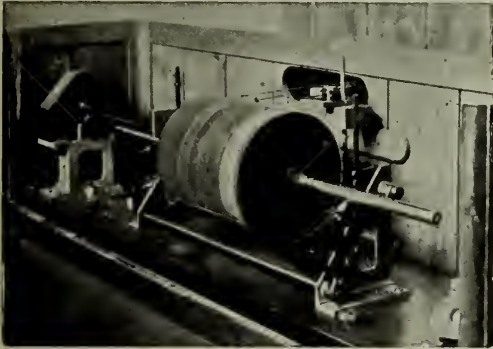
Suppose all the inhabitants of France, say forty million persons, were placed in

one pan of a gigantic pair of scales, and that they were counterpoised by weights, do you think the addition of one middle-sized boy to the population of the scale pan would be observed by the man who was weighing them? That is the sort of difference that had to be measured — a difference of one part in seventy or eighty million parts. Or perhaps it would be more correct to say that the degree of perfection to which the art of weighing was brought by Professor Poynting was such as would be required to detect, in this imaginary experiment, such a trifling detail as whether or not the boy had both his shoes on!

In measurements of this sort, the operations are of so delicate a character that the

sands of miles away! It was detected at Oxford, owing to the fact that Professor Boys was weighing the earth when the wave from the far-off upheaval traveled through the solid ground and shook his instrument violently.

If this instrument were used to mark the occurrence of an earthquake, it would be called a "seismoscope." But seismoscopes are not employed nowadays. They belong to the infancy of the science of earthquake study. What the modern man of science needs is an automatic recorder, which, in response to the slightest tremor of the ground, will write down or photograph all the curves of the movement. This is called a "seismograph." In principle it looks like a mast with a boom jutting from the



THE MACHINE BY WHICH AN EARTHQUAKE "WRITES" AND THE RECORD IT MAKES

The seismograph is an automatic recorder of earthquakes, so sensitive that the slightest tremor of the earth is registered. Light falls on a roll of photographic paper through a slit in a metal plate, making a thin line on the paper. The vibration moves the slit so that the line wobbles up and down; and the extent of the wobble indicates the intensity and the duration of the shock.

passage of a railroad train in the neighborhood may be a grave source of trouble. In 1894 Professor C. V. Boys was working at Oxford on the same problem of the density of the earth. He was using the astonishing threads which are made of melted quartz. These are incomparably finer than the finest wire. A single grain of sand, spun into one of them, might yield a thread a thousand miles long. These threads surpass steel in strength, and they are marvelously elastic. Armed with them, Professor Boys was able to make what is probably the best measurement yet obtained of the mean density of the earth: he fixed it at 5.5270. In the midst of his measurements, however, there was a mysterious disturbance. An earthquake was taking place some thou-

base. At the far end of the boom is a thin metal plate with a slit in it. Beneath the slit is a box carrying a roll of photographic paper, driven by clock work. At the top of the box is another slit, immediately underneath the slit on the boom-plate. A beam of light falls through both slits on to the photographic paper, and prints on it a sinuous line. Every vibration of the earth causes the boom to move; the position of the slit at the end is then altered, and the line printed on the photographic paper wobbles up and down correspondingly in consequence.

The study of earthquakes strikes the imagination chiefly by reason of the strange, terrible and disastrous power that bursts out in the great catastrophes of our planet. The man of science, however, is

but little interested in the largeness of the tremors of the earth. The small waves running through our apparently solid earth now seem to him to throw more light on the great problems than do the fierce shocks of some wild and sudden upheaval. At the present time he is mainly concerned in tracing movements of the earth so small that the vibrations due to the traffic in a city compare with it as the waves of the ocean with the ripples on a pool.

Two types of short waves are frequently observed. One has been traced to the action of the wind, which is found to create waves in the land just as it forms waves in the sea. A still smaller vibration, which occurs every five or ten seconds, appears to be due to the impact of billows on the shores of the earth; and experiments are now being carried out by means of an extraordinarily delicate instrument. It works automatically. The almost imperceptible pressure on the air which a wave of the sea produces, as it travels to the land, is transmitted by an electrical arrangement to a pen. The pen writes out the record of the pressures on a strip of paper, and when it has filled a page it automatically returns to its original position, and starts writing on a new sheet. So exquisitely balanced are the finest earthquake measurers that they are thought to be able to record dim waves in the ground representing the echoes of great earthquake shocks that originated a century ago.

Measuring the heat of a candle a mile and a half away

Is not all this a wonderful extension of our naturally dull sense of the movements around us? Our sense of heat has now become almost as fine as our sense of movement. By means of the bolometer, for instance, the heat of a candle can be felt at a distance of a mile and a half.

This instrument consists of a very fine platinum wire connected with three other wires to form a square. Two diagonal corners of the square are attached to the terminals of a battery, while the other two corners are connected to a sensitive galvanometer. The four wires are of such electrical resistance that the

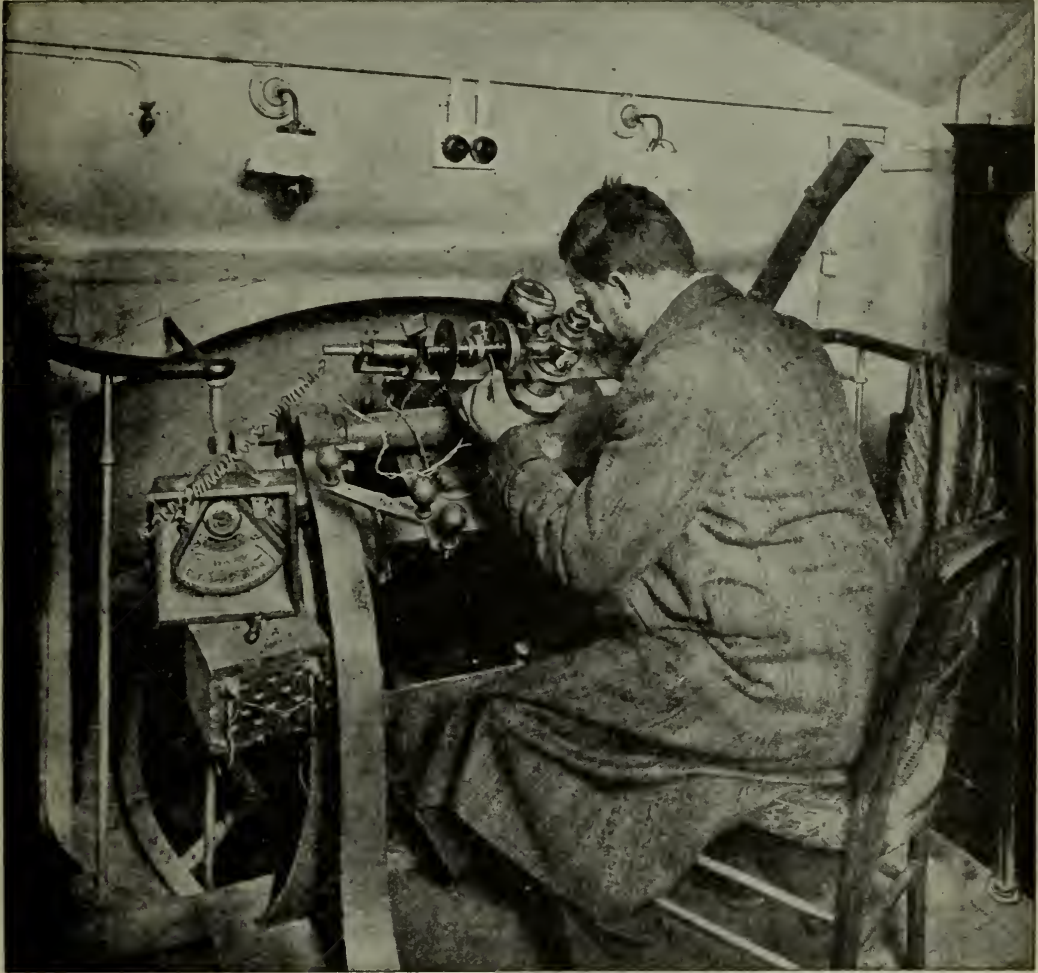
battery current flows only through the wires and not through the galvanometer. If the fine platinum wire, which is blackened so that no heat is reflected, is now subject to the radiation of some distant source of radiation energy it will become heated. Now, platinum and most other metals have an electrical resistance which increases with their temperature. The slightest change of resistance in the platinum wire, however, upsets the electrical balance of the system of wires, and causes a small current to flow through the galvanometer. A deflection of the galvanometer is magnified by a mirror mounted on the moving element, which reflects a beam of light from a fixed source on to a distant scale. The heat of a star millions upon millions of miles away may thus be measured in an astronomical observatory. The bolometer is of even greater importance in detecting radiation energy to which the human eye is blind. Place a glass prism in the sunlight, and the spectrum which we see begins with red and ends with violet. But if we place the blackened platinum wire of the bolometer in the region beyond the red, we shall be able to detect and measure the invisible radiation energy which vibrates too slowly for the eye to perceive.

The new eye of man which follows the track of a star

The development of photography has had many happy effects on science. The camera is a new eye, with a super-human steadiness, swiftness and strength. Without it man could not observe closely an object moving at high speed. In testing big guns, for example, the human eye cannot pick up the projectile in its flight, but photographs can be taken although the projectile speed may be 2500 feet per second. Placed at the end of a telescope, the camera watches the sky without growing weary. Following the track of a star so remote that its ray falls through the abyss of heaven with a faintness making it invisible to the most powerful telescope, the camera slowly collects the dim light, hour after hour, and reveals at last to the astonished astronomer a new sun.

A brief comparison will help us to appreciate what the camera has done for only one branch of science. Let us leave out of consideration the very useful part it plays in photo-microscopy and other methods of minute measurement. We will take only photo-telescopy. A keen-sighted observer might count with his naked eye two thou-

In the great wireless telegraphy stations, in which messages are received from points thousands of miles distant, the photographic plate has been found to be indispensable. By means of it the marvelous work of Marconi has been made a practical success. The signals are now sent at so high a rate of speed that no



MEASURING THE TEMPERATURE OF A STAR

By examining the spectrum of a star an astronomer can tell of what elements the star is composed. By experiment in the laboratory he can determine exactly the amount of heat necessary to convert various substances into light-giving gases, and he can examine their spectra. When he sees in the spectrum of a star the elements which are transformed into gases at a low temperature, he knows that the star is not very hot. Hot stars are violet, indigo and blue in color, while the cool stars are yellow, orange and red.

sand stars — or a few more — in an exceptionally clear sky at night. The finest telescope reveals tens of hundreds of thousands of points of light. Now, with the aid of the camera and the ultra-violet rays there is being made an international star-map which will definitely show the position of about thirty million stars.

operator could read them by sound or sight. So a galvanic battery is connected with the receiving apparatus, and the movements of a filament are reflected and photographed upon a sensitive strip of paper which winds along at a suitable rate of motion. Attached to the battery is another wonderful magnification of the

human senses. Perhaps it would be more correct to say that it is a new sense rather than the magnification of any existing power of mankind. It is sometimes called a "detector" and sometimes a "coherer." Its function is to detect the ripple of electric force which is the agent in wireless telegraphy.

How the mind of man peered beyond his senses

The existence of electric waves was known before they were discovered. This is one of the instances in which the human mind was able to anticipate the evidence of its senses. In 1864 sufficient facts had been collected to enable Clerk Maxwell to draw out a theory of electric waves; and the waves were found by Hertz in 1888. Hertz produced electric sparks, and made these sparks shoot backwards and forwards between two sheets of metal. At every to-and-fro movement of the sparks an electric wave was sent off; and by touching with a key the door-knob and other pieces of metal anywhere about the room, new sparks could be obtained. This had already been done by Professor Silvanus Thompson, who, in 1874, had made a detector with two door-keys, and had walked about the room collecting sparks.

It never occurred to him, however, that the existence of the new sparks showed that electricity had been given off in the form of waves. Hertz used his detector — a bit of wire bent into a ring so that the two ends nearly met — to measure the places where the electric sparks could be obtained apparently from the air — though really from the ether. By this means he measured the wave-lengths. He then showed that they were really waves — like the light-waves — by reflecting them in new directions by mirrors. Thus the idea of wireless telegraphy was born.

The great discovery that made wireless telegraphy possible

But the electric waves could not be used to transmit signals over any great distance. As they went out in long and longer ripples in the ether, they became too feeble to be detected by any existing instrument.

So men had to invent a new sense. A great French scientist, Professor Branly, thought out the difficult problem, and at last discovered the coherer. He found that certain metal filings resisted the passage of an electric current; when, however, an electric wave fell on the filings, they cohered, and allowed the electric current to pass. A wire connecting a battery to a bell was cut, and a tube containing some metal filings was inserted between the two ends of the wire. When the faint electric wave arrived, too weak to emit a spark or show its presence in any way, it was conducted to the filings. They then cohered, and the current from the battery rang a bell, or gave some other signal. Various forms of detectors have since been discovered; and it is owing to their extraordinary fineness of response that man is able to make the electric wave carry his messages to the ends of the earth.

The magic X-rays which shine through solid matter

To Hertz, the discoverer of the electric wave, we are somewhat indebted for the still more marvelous creation of the X-ray. Pursuing the researches of Sir William Crookes, he sent a current of electricity through a glass tube which had been emptied of air. A strange ray — called the "cathode ray" — was produced at the cathode, or place where the current leaves the tube. Hertz found that the cathode ray had the power of passing through very thin metal films. Röntgen emptied the tube more completely of air than Hertz had done, and the current he then sent through it endowed mankind with a new power of vision.

Thus was created the magic X-ray which shines through matter. It enabled man to peep, as through a crack in an enchanted door, into a universe of new wonders. In 1896, a few months after Röntgen announced his discovery, the door was flung wide open. Henri Becquerel in France and Silvanus Thompson in England found that uranium emitted an invisible ray; and, following out this indication, Madame Curie and her husband discovered the new element of radium, derived from it.

When the nineteenth century closed, man had to reconstruct the foundations of several of his chief sciences. Armed with the cathode ray, Sir J. J. Thomson broke up the atom, and showed that the ultimate form of matter was electricity; everything then became possible. A few years ago Sir J. J. Thomson again startled men of science by inventing an electrical method of analyzing elements in a cathode tube and taking photographs of the rays.

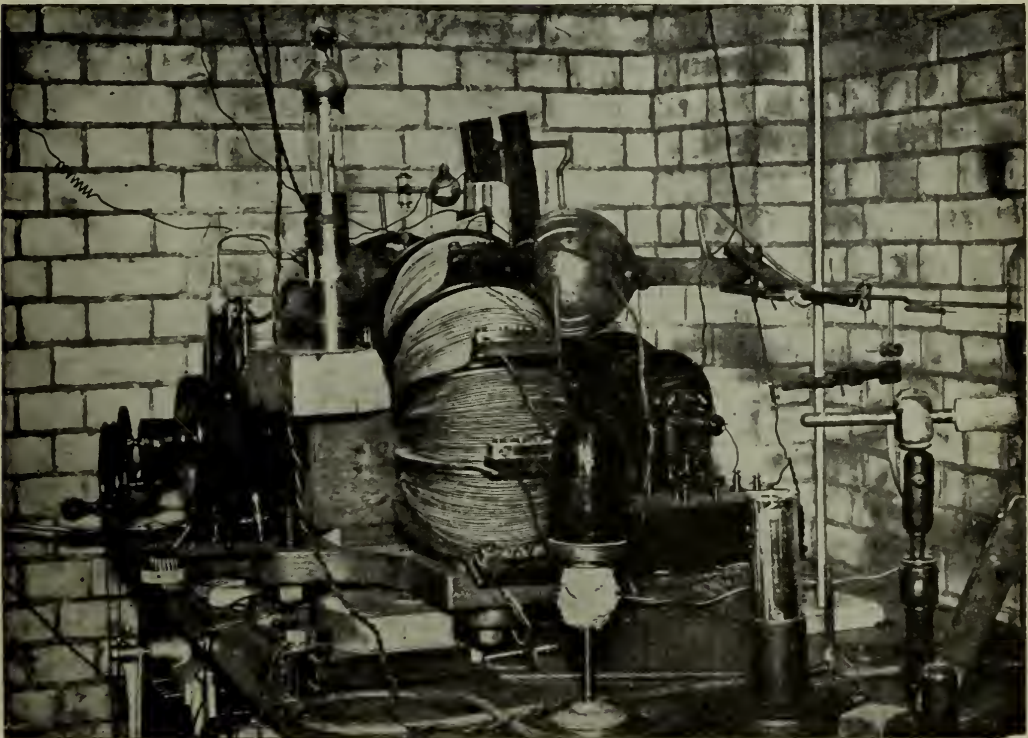
Practically all the tremendous progress of modern knowledge has depended on the invention of exquisite and often small pieces of mechanism by which man has magnified his senses. We no longer have five senses—we have hundreds. With his five senses, man in the ancient civilization could erect colossal works by lashing thousands of slaves to the task of dragging along huge masses of stone over wooden rollers. With our hundred senses we can set an iron slave to do more and better work than a host of serfs. Each little

instrument we invent to measure something that we cannot see or hear, taste or touch, is a fresh source of power.



SIR J. J. THOMSON AT WORK IN THE FAMOUS CAVENDISH LABORATORY, CAMBRIDGE, ENGLAND

When we learn to use our new powers fully, this age of transition will come to an end, and a new age of vital power will dawn.

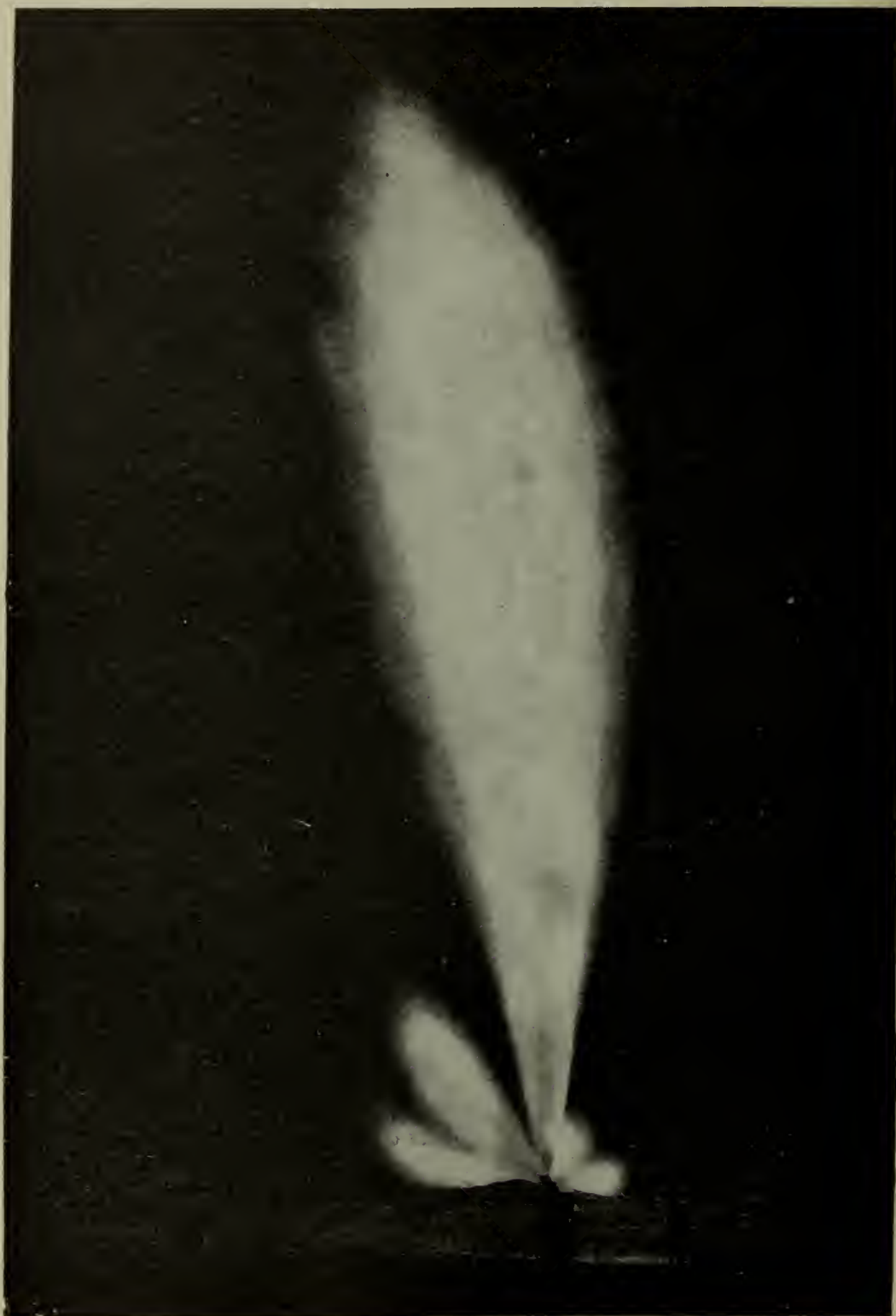


SIR J. J. THOMSON'S CATHODE TUBE

When a current of electricity is sent into the tube at a point called the "anode," it strikes against an opposite point, which is termed the "cathode." If the tube contains some rarefied gas, a cathode ray is produced; and it was through examining these cathode rays that Professor Thomson found that the gas had been split up into minute corpuscles of negative electricity.

When the cathode ray strikes against the glass of the tube it is changed into the X-ray that Röntgen discovered.

A FLAME THAT ROARED LIKE THUNDER



THE TREMENDOUS POWER OF NATURAL GAS — A FLAME, KINDLED BY LIGHTNING, WHICH ROARED LIKE HEAVY THUNDER AND BURNED 200 FEET HIGH FOR FIVE WEEKS, IN KANSAS

THE WORLD'S REAL WEALTH

The Millions of New People Coming into the
World and the Effect on World-development

USING UP THE ENERGY OF THE FUTURE

LITERATURE abounds with terms in which the world is expressed as huge, enormous, but the astronomical student soon finds cause to revise his early conceptions of the greatness of the planet which is his moving observatory.

He learns that the earth is small, even as compared with some of the other bodies bound by gravitation to the sun, and that the sun, which dwarfs the earth to comparative insignificance, is himself a star of no great order. But it is not only in relation to the cosmos that the earth has exceedingly narrow limitations. It is of the utmost importance for the student of commerce to realize that the planet we live on is small even in relation to man himself and to the needs of man. It is not necessary to use the earth's orbit as a measuring line to realize how man is "cabin'd, cribb'd, confin'd" within borders by no means too great for his needs and aspirations.

We are not concerned here with the possibilities or probabilities of the remote future, and the prophecies of certain astronomers as to mankind perishing on a waterless planet need not detain us. Considering merely the near future, however, in the sense of the next few generations, it is of profound importance to observe that the rapid increase in the number of men, combined with the rapid increase in the standard of life of nearly all men, makes a general survey of the earth's resources incumbent upon us if by industry and commerce we are to furnish forth in amplitude the material framework of civilization, and supplies to maintain thousands of millions of highly developed human beings.

It is difficult to estimate even approximately the rate of increase in the world's population as a whole, but the increase of the great white civilization alone is over six millions a year. Comparing the figures for 1830 and 1880 with those of 1920, for a number of leading countries, we find a remarkable advance. The facts present abundant food for reflection to all who are interested in the development of mankind.

RISE OF POPULATION IN GREAT COUNTRIES

(The figures are given in round millions)

COUNTRY	1830	1880	1920
United States	13	50	106
Canada	—	4	9
Mexico	—	10	14
Argentina	—	3	10
Brazil	—	12	31
Chile	—	2	4
Great Britain and Ireland . .	24	35	43
France	33	38	39
Germany	30	45	59
Russia	55	85	102
Austria-Hungary	30	38	—
Italy	21	28	39
Japan	27	36	56

In the last century and a quarter the population of the United States has grown by over one hundred million. We are too likely to think of this phenomenal increase as something unique and unparalleled. It is, in fact, merely an unusually striking example of the way in which the development of commerce and communication, the opening up of new resources and the resulting industrial coöperation of the whole world have brought about an enormous increase in the number of human beings.

In the last two hundred years or so the population of the world has just about doubled. This is possibly the most significant single fact of modern history.

In 1760 there were probably not more than 130,000,000 people in all of Europe. In 1914 there were 450,000,000. Half of this increase was subsequent to 1872. The population of England in 1761 was only 6,700,000, and it was probably as much as 6,000,000 two hundred years before that date. By 1831, when England had come to rely more largely upon commerce as a source of wealth, although she was still trying to raise most of her own food supply, the population had more than doubled. Since that time England has developed her manufacturing and commercial interests and has imported a larger and larger proportion of her food supply and raw materials from newer countries. As a result, England now supports a population of nearly 40,000,000 people on a higher average level of comfort and well-being than was possible for her 7,000,000 inhabitants a hundred and fifty years ago.

It must not be thought that this growth of the populations of the western world has been at the expense of the more backward peoples. Wherever commerce has carried western civilization and industrial methods the numbers of the native population have more often increased than decreased. Such, for example, is true of the Indians of Mexico and of South America, who are more numerous than they were at the time of the discovery of America. Such also is true of the native population of the Philippines, of India and of Egypt. Japan offers a striking illustration. For at least a hundred and fifty years before it opened its doors to the commerce of other nations its population had remained nearly stationary. Since 1871 it has increased from 33,000,000 to approximately 60,000,000.

Japan is not an isolated instance. The island of Java has grown from about 4,000,000 in 1800 to nearly 35,000,000. That island, only one-third as large as the state of California, now contains about one-third as many people as the whole

United States. Viewing the whole experience of human history, we are entitled to say that millions now live where nature grudged existence to thousands.

The potentiality of a great nation that comes new into the world every year

The birth-rate of the white peoples has been falling, but their death-rate has been also reduced; and with the progress of preventive medicine we may expect a further improvement, especially in infantile mortality. There is every reason to believe, therefore, that the near future will witness the continued multiplication of mankind. The importance of a proper distribution of the world's production will consequently increase, and the leaders of men will be driven by necessity to greater efficiency in the production and distribution of food and other commodities. The world's population is approximately 1,600,000,000, and in recent years it has been increasing at the rate of about 20,000,000 a year. We have to endeavor to realize that the world's resources are drawn upon each year by an additional mass of people as great as about one-fifth of the population of the United States. The earth gains in twelve months enough new people to make a new great nation.

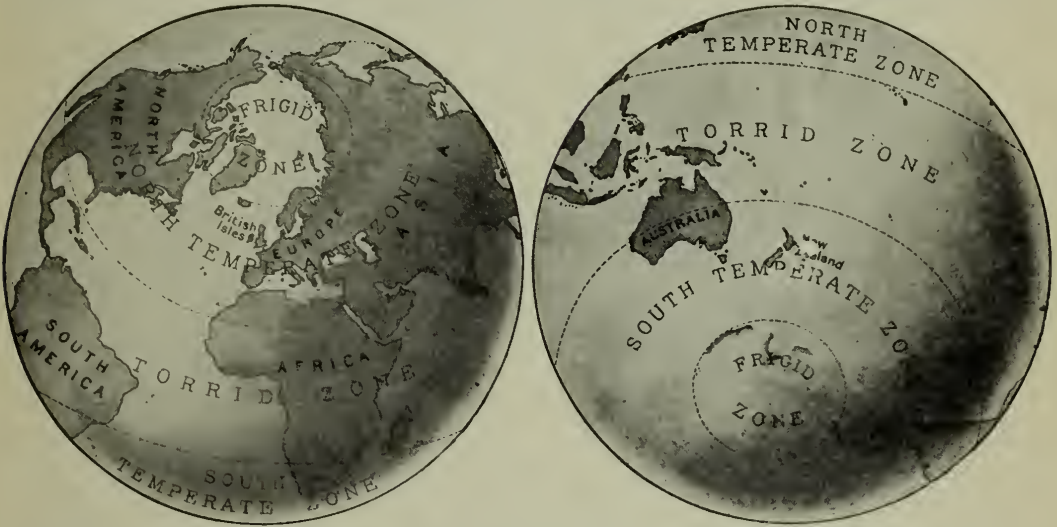
Man has already explored and mapped nearly the whole of the land surface of the earth, which occupies about one-fourth only of the world's area. The land surface of the earth is about 53,000,000 square miles; and it is of interest for the American reader to note in passing that the United States cover about 2,970,000 square miles, or less than 6 per cent of all the world's land, and that it contains just about the same proportion of the world's population. The density of its population, therefore, is a fair sample of that of the land surface of the earth taken as a whole.

The distribution of land upon the earth's surface presents some remarkable features. By far the greater part of the land lies north of the equator. The great continental masses taper to the south. The northern hemisphere contains most of the land of the world; the southern is nearly all water surface.

The half of the world in which the greater part of its work is done

It is in the north temperate zone that the greater part of the world's work is done. Here live the majority of the world's white people. In the south temperate zone there is comparatively little land, and here are to be found the million whites of South Africa, the 5,000,000 whites of Australasia and part of Latin America. In the torrid zone is the greater part of the African continent, the Indies, and a large part of South America.

ter, therefore, seems to be opened in the history of the advance of man's control over nature. If the white man can successfully wage war on the mosquitoes and other flies which introduce these diseases into his blood, he can live and work in tropical countries. The history of these researches is a magnificent story of heroic devotion to the cause of science and of human progress. It was through the heroism and martyrdom of Reid, Carroll, and Lazear that it was proved that yellow fever could be spread only by the bite of a mosquito and only by a single species of



THE TWO HALVES OF THE WORLD, SHOWING WHERE MOST OF THE WORK OF THE WORLD IS DONE. One hemisphere, which includes the north temperate zone, contains most of the land of the world; that including the south temperate zone is nearly all water. It is within the former that most of the white people live and most of the world's work is done.

The researches of recent years have given an entirely new aspect with respect to the possibility of colonizing the tropics. For hundreds of years it had been thought that the white man could not live or at least could not work effectively in a tropical climate. Climatic considerations, therefore, seemed to indicate that the tropics must forever remain in a relatively undeveloped condition; that the temperate zones alone could be the home of an advanced economic civilization.

But we have now come to realize that the barriers to the economic development of the tropics have not been so much excessive heat or excessive rainfall as the presence of insects that have conveyed such dread diseases as yellow fever, malaria, and sleeping sickness. A new chap-

mosquito. Havana, formerly a plague center, was cleaned up and rid of the disease during the period of American occupation. By far the largest and most significant test, however, is to be found in the elimination of yellow fever and malaria from the Panama Canal Zone by United States government enterprise.

In the days when French companies were at work on the canal, construction proceeded slowly and at enormous cost of life. Parties of vigorous young Frenchmen went out to Panama, to perish or to become permanent invalids. The United States government began by preventing the breeding, on the Canal Zone which they purchased from the Panama Republic, of the two varieties of mosquitoes which respectively convey malaria and yellow fever.

The hope that science will open the gates of the tropics to commerce

As a consequence, these diseases have been entirely banished from the Canal Zone. The average death-rate of all employees during the ten years of digging was only 1.7 per cent; and the chief sanitary officer, the late Colonel W. C. Gorgas, gave it as his opinion that it has been conclusively proved that white men can colonize the tropics, the torrid zone. He says: "I think the sanatorium can now show that any population coming into the tropics can protect itself against these two diseases — malaria and yellow fever — by measures which are both simple and inexpensive; that, with these two diseases eliminated, life in the tropics for the Anglo-Saxon will be more healthful than the temperate zones; that gradually, within the next two or three centuries, tropical countries, which offer a much greater return for labor than do the temperate zones, will be settled up by the white races; and that again the centers of wealth, civilization, and population will be in the tropics, as they were in the dawn of man's history, rather than in the temperate zone, as at present."

When we remember that at the tropics the fruitful earth gives a succession of crops throughout the year, and that many most valuable natural products can only be raised in a tropical climate, we understand how much the scientific conquest of the equatorial regions may mean to the future of mankind. At present, however, such developments are little more than in embryo, and the industrial and commercial leadership of the world is centered in the North.

Redistribution in the present to be even greater than in the last century

Consideration of the important figures on a preceding page will show what enormous changes in the character and direction of the world's commerce have been caused by the redistribution of a great part of the world's most gifted races. This redistribution is not only continuing, but accelerating; and the twentieth century

will witness changes even more remarkable than those revealed by our survey of the development of Christendom in the last century.

New lands will gain increasingly by immigration, and by the export of capital from settled countries, as well as by their own native increase, and as a consequence commerce will greatly change in volume and in nature as between various parts of the world.

What are the great economic forces which determine these changes in the distribution of population and of the world's industry and commerce? The answer to this question is a key to the proper understanding of the world's activities, and of the greatness of certain nations.

Important factors which determine re-distribution of population

The first and most important factor is the distribution on the world's land surface of considerable supplies of energy stored by nature in a form available to man.

So far we have learned to obtain supplies of power on a large scale in only two ways — by the combustion of fuel and by the harnessing of water-power.

Other sources of power are, of course, known to science, from the wind to radium, but none of them is of practical importance. It may be remarked in passing, however, that the extraordinary and almost miraculous emanations of energy exhibited by radium — fully considered elsewhere in this work — may lead to a complete revolution of our conceptions of power-getting, and so alter the face of the world and the life of man as to render all that is written here obsolete and valueless. Dealing here with the world as we know it, and with scientific attainment as it is, we are compelled to recognize the all-importance of the distribution of the world's great stores of fuel, and of the world's great sources of water-power, bearing in mind that these factors determine the distribution of industries, and therefore the centers of population, and therefore the direction and nature of commerce.

Let us consider, first, the distribution of the world's fuel.

The fuel that determines the industrial leadership of the world

Fuel is known in a number of forms, as wood, as peat, as coal or lignite, as oil, as gas, or as alcohol, and each of these forms has been utilized in practice for industrial purposes. Let us pass them in review.

Wood can be indefinitely increased by man, although at a relatively high expense. The passing of wood as industrial fuel will be understood when it is remarked that the iron and steel work of the United States, if now accomplished by wood fuel, would call annually for more timber than is today growing within the United States.

Peat fuel is of considerable value, but the supply does not make it of much importance as an industrial factor.

Coal in its various forms exists in enormous quantities in various parts of the world. It is invaluable, and at present indispensable and unrivaled, as a readily available source of energy. Lignite, or brown coal, only less valuable than coal itself, has also a wide distribution.

Petroleum is in many respects more useful even than coal, but the world's supplies are comparatively not very great, and are not likely to last so long as the world's coal reserves.

Natural gas is another fuel of great value, but the supplies are comparatively insignificant and must be used within a relatively small radius of the place of production. The immense force of this gas can be seen on page 254. The natural gas which caught fire, as shown in this picture, had a force practically uncontrollable, so that the fire lasted five weeks, having discharged gas during that time at the rate of almost three-quarters of a million cubic feet a day. We may almost ignore the commercial value of natural gas, however, even though it has taken on a new importance as the source of "casing head" gasoline.

Alcohol is an excellent fuel, which can be produced from organic sources, such as the potato, in practically unlimited quantities, but it is not an economic rival of coal or of oil in places where those fuels are found in quantities.

Coal thus stands out as the supreme fuel, and therefore as the arbiter of the distribution of industry depending on fuel. But, while the world's coal is enormous in quantity, its distribution is most unequal. The chief coal areas are situated in North America, in China, in the British Isles, in Germany, in New South Wales, and in Russia. Coal area, however, is a very different thing from accessible coal — that is, coal at not more than half a mile, or at most 4000 feet deep. Much depends, too, upon ease of transportation, or upon proximity to iron-ore deposits, so that steel-making may be practicable. In coal thus available, the United States, the United Kingdom, Germany, and China appear to have the best now known; and the three former countries have consequently led the world of industry and commerce, though in the time to come an awakened China may possibly rank with them as a great coal power.

The great natural source of energy that is practically inexhaustible

We come now to the second great source of energy — the world's water-power.

The water-power here considered, it must be remembered, is that which science has rendered available. So far, engineers have decided that tidal power cannot be used economically. Great use is already being made, however, of mountain streams and waterfalls in the countries fortunate enough to possess them. Niagara is now the center of great industrial operations. In France, in Switzerland, in Italy, in Norway, in south Germany, and elsewhere, great developments are in progress, and the term "white coal" has been coined to express the economic value of water-power.

A moment's consideration of a map of the world, and of the mountains and streams thereof, will show the student that "white coal" is as unevenly distributed as coal itself, and that sometimes a coal-less land possesses water-power. Water-power has this advantage over coal: that it is for practical purposes inexhaustible, whereas a fine coal-field may be creamed of its best within only two generations.

This broad review of the world's power supply enables us to picture modern machine industry as grouped in natural power areas, and we see the great coal civilizations standing out supreme, because based upon the extraordinary economic advantage which the possession of coal gives them. It is in part because the United States is the greatest coal producer in the world that she has so rapidly assumed industrial leadership.

The immense increase in the wheat-fields of the world

We pass to the second great determinant of the distribution of the world's population. This is fertility. The great industrial populations, grouped, of necessity, upon coal and water-power areas, call for enormous supplies of food and raw materials — organic and inorganic. The gigantic increase in the demand for food, caused by the multiplication of wealthy industrial populations, may be illustrated by the growth of the world's wheat crops in recent years. Here are the figures of the production for twenty-four recent years throughout the world :

THE WHEAT CROPS OF THE WORLD FOR TWENTY-FOUR YEARS

YEAR	BUSHEL	OF WHEAT	YEAR	BUSHEL	OF WHEAT
1902	. .	2,949,000,000	1914	. .	3,581,000,000
1903	. .	3,024,000,000	1915	. .	4,272,000,000
1904	. .	2,725,000,000	1916	. .	3,303,000,000
1905	. .	2,987,000,000	1917	. .	3,245,000,000
1906	. .	3,099,000,000	1918	. .	3,678,000,000
1907	. .	2,800,000,000	1919	. .	2,997,000,000
1908	. .	2,968,000,000	1920	. .	3,033,000,000
1909	. .	3,360,000,000	1921	. .	3,317,000,000
1910	. .	3,229,000,000	1922	. .	3,400,000,000
1911	. .	3,525,000,000	1923	. .	3,742,000,000
1912	. .	3,812,000,000	1924	. .	3,018,000,000
1913	. .	4,037,000,000	1925	. .	3,511,000,000

There has thus been an increase of about 50 per cent in the world's wheat production in a quarter of a century. Wheat is the most prized of the grasses of which all flesh is made. It is the aristocrat of the cereals, and the staple food of the most advanced races.

The increase in the production of wheat is partly due to the increase of population of the nations of Christendom which we have already considered, and partly due to the world's rise in the standard of life.

Many consumers of inferior foods in Europe have emigrated to the New World, and become consumers, or increased consumers, of wheat, meat, and other prized foods, which the higher standard of living — and of wages — encourages and permits.

The most extraordinary period of expansion that the world has ever known

It is very remarkable that, although the increase in the wheat supply has been greater than the increase in the population, the price of wheat, as we shall see, has considerably increased in the period examined, showing that demand has risen even more rapidly than supply. The broad fact is that while, in the last fifteen years, the world's wheat has increased in quantity by 50 per cent, its price has also increased by 50 per cent. This is symptomatic of the most extraordinary period of industrial and commercial expansion that the world has ever known. The resources of the world are now being exploited on a scale which transcends all former experience. The quantity of iron brought to market in the world is one of the best indexes of industrial and commercial expansion. Testing the work of the world by this sure standard, we get the following measure of progress :

THE WORLD'S PRODUCTION OF PIG-IRON FOR SEVENTY-FOUR YEARS

YEAR	TONS OF IRON
1850	 4,000,000
1860	 7,000,000
1870	 18,000,000
1880	 12,000,000
1890	 27,000,000
1900	 40,000,000
1910	 65,000,000
1924	 65,000,000

These facts are eloquent of the rapid march of industry and commerce. Steel is the basis of modern work, and the vastly increased use of steel spells a marvelous addition to the world's railways, steamships, and industrial plants. This record shows at a glance the rapid rise in the standard of wealth and comfort, which is leading to an ever-increasing demand for wheat bread.

THE FATHER OF WATERS AS A FURNISHER OF POWER

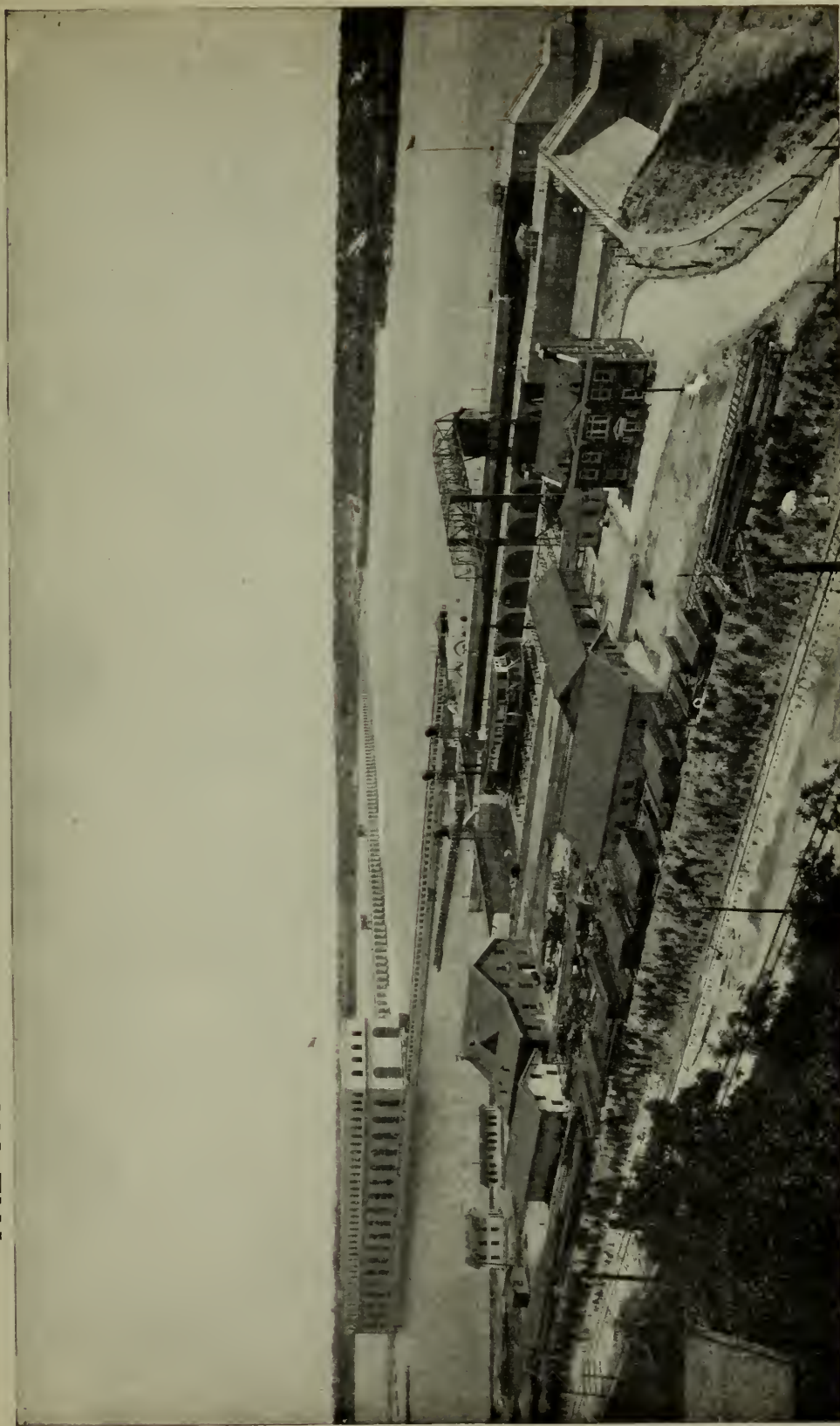


Photo Anschutz

View of the 150,000 H.P. power plant on the Mississippi River at Keokuk, Iowa, which supplies electric power to St. Louis, 144 miles away. The barrage is 4278 feet in length, and the power house contains 30 electric units with a capacity of 7500 kilowatts each, or an aggregate of 225,000 kilowatts.

The attraction to emigration of "fresh fields and pastures new"

The circumstances we have reviewed enable us to comprehend the great streams of emigration which flow from the Old World to the New. We see industrial workers attracted to great power areas, and the natural fertility of new lands — very literally "fresh fields and pastures new" — attracting from the long-settled and comparatively crowded lands of the Old World workers anxious to pass from lands where every yard of ground has been worked over to these spacious territories of the New World whose virgin fertility enables crops to be raised for the scratching. We see the agricultural group of emigrants going forth to help feed the world's industrial workers. As a consequence, old streams of commerce are invigorated and new streams arise. An ever-increasing number of freight cars and steamships is needed to transport the expanding surplus natural produce of such countries as Australia, Canada and Argentina and of the western United States, to allow of their exchange for the manufactured productions of the great industrial centers of their own and other countries.

The two million people who move about the world every year

Such will continue to be the development of the world of commerce for a great part of the twentieth century. Nearly two million people a year are now transplanting themselves from one part of the world to another, and the settlement of new countries is proceeding apace. New and vast populations are growing up in hitherto unpeopled areas. There is obviously a limit to such a process, even under existing conditions; and the more the pace of emigration is accelerated with the spread of better knowledge and understanding of what the world as a whole has to offer, the more rapidly the process must end. The natural fertility of new countries, moreover, is by no means inexhaustible, and the governments of the New World have little land left to give away to settlers.

Beyond lies the possibility of such gifts by science as shall, by cheapening power, or by making power more evenly distributed in the world, lead to a new settlement of mankind on the globe. There is besides always the possibility also of the control of climate and of fertility to an extent as yet entirely undreamed of.

The consequences of bringing the world's wealth to market unscientifically

Commercial questions of the deepest importance to man are raised by what we have now considered. We have seen with what rapidity world-development is proceeding. Few secrets are now withheld from geography, and the engineer is covering the 53,000,000 square miles which is the basis of all mankind with a network of railways, rendering easily accessible all the world's remaining native fertility, all the world's forests, and such of the world's minerals and metals as can be got by discovered methods. We thus get a picture of all the world's wealth brought to market as it has never been brought before. The figures relating to the production of wheat and iron are typical of all, or nearly all, of the foods and commodities which are required by man.

We have not taken sufficient thought so far in our dealings with our small world. Within a recent period of history — within the lifetime of many of those now living — man has become possessed of extraordinary powers over the forces of nature. Armed with the powers conferred upon us by physical science, we have addressed ourselves to a world which but yesterday appeared limitless in natural resources. We have hastily plowed over virgin soil and have exhausted it, as in some parts of the United States. Too frequently we have converted our agriculture into a process of "mining" the thin top layer of natural fertility in the soil. We have laid waste magnificent forests without regard to the fact that three generations cannot restore what can be hewn in a year. We have skimmed the cream from some of the world's richest and most easily worked mines without, it is to be feared, much regard for posterity.

Why our increasing population faces ever a rising cost of living

That is why the increasing population of the world, despite the enormous industrial and mechanical improvements of the past century, still has to face a constant tendency of the cost of living to increase. The necessities of life—food and raw materials—come from the extractive industries—agriculture and mining. No amount of mechanical progress or of perfection in the means of communication can by itself stop for long the resistless pressure of population upon the necessary means of existence.

We have cut down our great forests with a light heart; we have exhausted nature's supply of rubber and have had to turn to artificial plantings; we have used the best and the most accessible of the world's iron, of the world's tin, and of the world's copper, as well as of the world's coal and petroleum. We have grown wheat and cotton on fertile lands year after year, without rotation of crops, until within less than a generation the fertility of the land is so greatly reduced that we have had to move our wheat and cotton-fields farther on to lands whose natural fertility has not yet been impaired. In all this there is no cause for pessimism, but there is cause for thought. Rational policies, framed upon the basis of rational foresight, are necessary.

The necessity of international as well as national conservation

We are here concerned with matters of profound import of the future of the United States and of all mankind. It is increasingly evident that industry and commerce must be carried on with a greater regard to the conservation of the world's resources, and that ceaseless endeavor must be made to promote coöperation between producing and consuming units throughout the world. The beginning of such efforts is fortunately already discernible, and the great nations are becoming more and more alive to the necessity of taking action in regard to this absolutely vital problem.

Canada and the United States take steps to prevent further spoliation

In the United States, a realization of the wanton waste which has long proceeded, and of the necessity of preventing further spoliation, led to the creation of President Roosevelt's Conservation Commission and to the general interest the subject has now gained. In the British Empire the Imperial Conference accepted unanimously a resolution, moved on June 16, 1911, by Sir Wilfrid Laurier, urging the appointment of the Royal Commission which has subsequently investigated and reported upon the natural resources of the Empire. In Canada stern measures have been taken to prevent further waste of timber.

Industry can provide for organic, only forethought for inorganic supplies

The problem before us is really two problems. In relation to organic supplies, such as foods, vegetable fibers, timber, rubber, vegetable oils, the problem is merely one of looking ahead and taking sufficient forethought. We can get by industry, and distribute by commerce, as much of these things as we need. With regard to inorganic supplies, the problem is of a very different order, and calls for the more serious efforts of science. A mine has a harvest, but no seed-time; and the prospect of an iron famine is near enough in the future of man to make the study of iron conservation, of the utilization of low-grade ores, and of the economic use of such partial substitutes as aluminum, a matter of much moment to all mankind.

It is the function of commerce to perform a synthesis of the world's activities; and there is no happier indication of advance in this direction than is to be found in the multiplication of international commercial conferences. When commercial men of all nations meet to consider the world's supplies of iron, of cotton, or of wool, and to ask how these things can be utilized with economy, the world is beginning to make the best use of its very limited resources.

A PICKING DAY IN SOUTHERN COTTON FIELDS



© Underwood & Underwood, N. Y.

Cotton is the most valuable of all the vegetable fibers of the world, and its growing, its spinning and its weaving employs more workers than any other industry. The United States, with its thirty-six million acres of plantations, supplies nearly three-quarters of the world's cotton. The fiber has to be picked by hand, and from a single pound of it may be spun a thread one hundred miles long.

THE COTTON OF THE WORLD

The Story of the Flower of the Field That
Gives Work to Millions and Clothes to All

THE SOURCE OF PROSPERITY OF THE SOUTH

AN interesting argument might be started as to which vegetable growth is most important to man. Is it wheat for the feeding of the man of the earth's temperate regions? Is it rice, for the sustenance of the people of the warmer climates? Is it the potato, which enables men to grow more food per acre than in any other way? Is it cotton, which clothes the vast majority of mankind, in part or wholly, and also indirectly provides valuable food? Is it the vine? Will it be the rubber tree?

While most of the people who read and write books would decide for wheat as the most important vegetable product, a case might be suggested for cotton, because admittedly its importance is enhanced by the fact that the earth does not provide any substitute for it. It is cotton or nothing for clothing the poor people of hot lands.

Whether cotton is or is not the most important vegetable product, it certainly is the chief vegetable fiber. Nothing similar is grown to such a stupendous extent, or occasions the expenditure of such varied manipulative skill. In its manufactured form it is known to every man between the Arctic Circle and the remotest equatorial swamps. Its growth has caused the greatest transplantation of a backward race from continent to continent whereof the world holds record. Gradually, too, its predominance is extending, for decade by decade it clothes an increasing percentage of mankind while its competitors in the world's clothing trade are falling farther behind in the race, even when they are not slackening their

pace. At present, cotton has no rival; nor will it have until a form of patent clothing is invented equally comfortable and attractive and cheaper. Mankind wears three times as much cotton as wool.

There is a striking universality in the use of cotton throughout the world, if not through time. Though wool was the ware in ancient Europe, and linen in ancient Egypt, the use of cotton was known, as an echo from the East. Herodotus was aware of the "fleeces from the trees," and admired their effect in fabric form. For nearly three thousand years, India has had cotton manufactures unsurpassed in certain qualities. The word "calico" itself is from the Indian town of Calicut. When the Spaniards appeared in America they found the natives of the southern continent wearing cotton garments so well dyed that they sent them home as curiosities and as proofs of the stage of civilization attained. The countries that now supply the world with its calico prints were backward in beginning the manufacture of cotton cloth.

The modern change has been brought about, of course, by the impetus of invention and an early start with machinery. Europe first received the industry from the Moors, and it is said to have come to England from the Turks by way of Flanders, but there was no considerable progress until Richard Arkwright invented his "water-frame" for spinning, which enabled an all-cotton fabric to be produced by machinery, cotton being used for both warp and weft. Then England began to make the world's cotton goods, and America to grow the cotton.

Cotton can be grown only where there is sufficient, but not too much, moisture, with plenty of sunshine. It is subject to many diseases, and, except under constant conditions of a favorable character, has a somewhat precarious life on the level of prosperity. It has a long growing season from first to last. Fresh seed is planted in March or April by machinery, on prepared and manured ground, from which last year's stems have been cleared, the rows being from three and a half to four feet apart, and the seed-holes not less than twelve inches distant from each other in the rows, and with not less than four or five seeds in each hole.

The beautiful ball of tuft that springs out of the bursting cotton pod

In May, after the plants have been thinned out, showers are needed, and the active period of growth is from early June to the middle of August. The plant rises as a shrub from two to four feet high, branching broadly at the bottom and much less broadly at the top. The flowers appear in June, and are very short-lived. On the third or fourth day they fall to the ground, after having turned from white or yellow to a darker and redder color, and they leave at the calyx a small capsule, which grows to the shape and size of a hen's egg, ripening, through dry weather, in August, and bursting open in September. The bursting pod, or boll, discloses a beautiful tuft of white lint, springing in separate hairs from the coating of a number of seeds.

The object of these gossamer protuberances is ultimately to float the seed through the air to its next year's growing ground. That, of course, is not allowed: the seeds and the attached lint are picked from the pods in time to prevent it. As the maturing does not all take place at the same time on the same plant, the gathering goes on for many weeks — through September and October into November. The picking, a picturesque but most tedious process, is done by hand as shown in our frontispiece, effective machine-picking being one of the great needs of cotton culture that are still unmet.

The ball of tuft that will make a thread one hundred miles long

The cotton plant is found in a wide tract of the world, its characteristics varying with kind, soil, climate, and treatment. It has long held its own in India, thrives well in Africa, and was indigenous to the West Indies and South America, but not to the United States, though the United States now furnishes about three-quarters of the supply of the whole world. It is really a perennial shrub, but is treated as an annual and is planted afresh each year.

Five different types of cotton may be distinguished from the rest — sea island cotton, the longest and best quality, grown along the coast region of the Southern States; long-staple upland cotton, an Asiatic type brought to America; short-staple upland cotton, of American origin, but carried to other countries — the most general form of the American product; tree cotton, an Indian perennial of low value; and bush cotton, an Indian variety used for muslins.

Let us trace the average cultivation of the average plant on an "upland" American plantation.

It is almost incredible to the stranger visiting one of the cotton-fields, as he gazes at the balls of tuft on the plant, that a single pound of the finished fiber from these balls can be spun out into a thread 100 miles long. Let us consider how this feat is achieved.

The cotton, when picked from the pod, consists two-thirds of seed and one-third of fibrous filaments, or lint. The usual cost of picking is fifty cents per 100 pounds weight of seed cotton, and a fast picker can gather 300 pounds in a day. A good average cotton crop will be about twice as remunerative as an average wheat crop at American prices, and is only half as exhaustive of the soil. A medium yield is say 190 pounds of lint to the acre, irrespective of the seed, which is worth about one-fifth of the value of the crop of lint. The picking of the cotton is always carried on in the sun; and after it is picked and loosely baled, or put in bundles, it is left in the sun to dry.

PACKING THE COTTON FIBER FOR SHIPMENT



The cotton, as it is gathered, is taken to a ginnery, where a machine like this separates the fiber from the seeds. The seeds, when pressed, give out a valuable oil, in which a great trade has been built up.

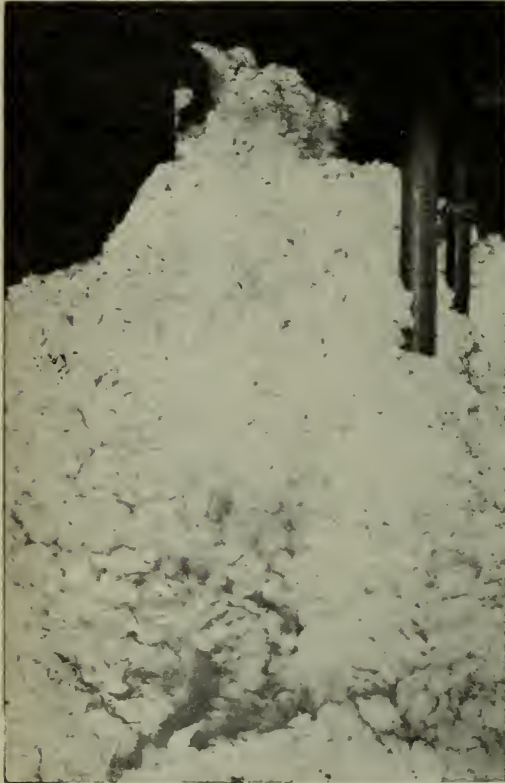


The cotton fiber is packed into solid bales by a hydraulic press, and is then fastened by iron bands ready for shipment to the cotton mills of the world. An American bale weighs five hundred pounds.

Photographs copyrighted by Underwood & Underwood, N. Y.

The invention that appeared the moment it was wanted

In the early days of cotton-growing, the separation of the seed and lint was the most tedious work associated with the plant, and kept down production. The remarkable rise of the American output dates from the invention of the saw gin by Eli Whitney, a Massachusetts man, who, after being educated at Yale, found himself a schoolmaster without employ-



RAW COTTON AT THE SPINNING MILL

Twenty-five thousand million miles of yarn are spun in England from fiber like this every year—a length 270 times as great as the distance from the earth to the sun. The United States alone grows each year 6500 million pounds of this fiber, more than enough to clothe every human being on earth in a cotton suit.

ment in South Carolina, and, seeing the need for a better gin, invented one. Since that time American cotton production has enormously increased, multiplying itself four thousand times.

In the case of sea island cotton, the seeds are but lightly entangled in the long and silky cotton fibers, and can be more easily removed, but in the upland cotton, which is the common crop, they are tenaciously attached. The second half of the

eighteenth century had witnessed great advances in spinning in England, culminating in Crompton's "mule," which would run 360 spindles at once.

But where was the cotton to come from to keep this new machinery at work? Obviously, it could not be supplied if the seeds were to be picked from the cotton by hand. Just at this moment came Eli Whitney's saw gin for tearing the lint from the seeds with such expedition that his machine and one man could do as much work in a day as two hundred men engaged in hand-picking—a rate of speed now enormously increased. It is true that the gin damaged and, indeed, continues to damage much cotton, cutting and breaking the fibers by its rough methods, but it gets through the work, and gives the multitudinous spindles of America and of Great Britain an ever-increasing supply of raw material.

In the earliest days of the saw gin it was erected, if possible, over a stream, in order that the seeds, as they were separated from the fiber, might be dropped into the current and swept away. All that is now changed; and the commercial value of the products derived from the seed, once treated as refuse, has grown to millions of dollars per year for the United States alone. If the cotton plant made no lint for the clothing of man, it would be worth cultivating for the value of its seeds.

The seed is sent to the oil-mills, and there is treated so as to produce cotton-seed oil, feeding cake for cattle, and fertilizers for return to the soil. At the oil-mills the seeds are first screened and cleaned, and then the remainder of the short lint still adhering to them is removed—less than 30 pounds being recoverable at this stage from 2000 pounds of seed. The seeds are then hulled—that is, sliced up by machinery—so that the outer coverings are separated from the kernels, or "meats." The "hulls," which are the lighter part, are screened away, and amount to about 850 pounds in 2000 pounds of seed. They are used to make bran for cattle food, and so serve indirectly as a manure, while the fiber makes a high-grade paper. The kernels, which

amount to about half the original weight, are crushed, then cooked, then placed under a hydraulic press, so that the oil is squeezed out. The solids remaining are next either ground into meal for a cattle food, or pressed into cotton-seed cake for the same purpose. The crude oil amounts to about forty gallons from a ton of seed. The settlings of the oil are used in soap-making, and the clearer oil is refined by heating, and by treatment with potash, which causes its impurities to be deposited. This refined oil is known in commerce as "summer yellow," or, in its purest forms, as "butter-oil," and it is used in the manufacture of oleomargarine and butterine. Under cold pressure it is changed into salad-oil, and becomes an alternative to olive-oil, or is sold as such.

The enormous production of cotton-seed oil in the United States

When bleached it finds a market as a substitute for lard, or is known as "cotton-lene." Under cold pressure it becomes "winter white oil," and is used in the manufacture of medicines, as well as for miners' lamp-oil and for soap-making. The United States alone has produced as high as 230 million gallons of cotton-seed oil in one year. In 1919 the production was 161½ million gallons valued at 210 million dollars. The most familiar form in which cotton-seed oil meets the eye of the householder is in the anchovy and sardine tin, the fisheries of western France being almost entirely supplied with cotton-seed oil from the United States and Egypt.

The price that raw cotton will command depends on the ripeness, length, and fineness of the fibers. Unripe fiber has to be removed ultimately. The farmer, when paying the ginner for his work, may wisely pay for the running of the machinery at a lower speed, so as to preserve the quality of his product and secure the exclusion of waste matter. After ginning, the cotton is forced into as small a bulk as possible under a baling-press, because freight is payable on bulk as well as weight. An average American bale weighs 500 pounds, an Indian bale 400 pounds, and an Egyptian bale 700 pounds.

The concentration of the growth of cotton in the American cotton-fields

The question of the concentration of the growth of cotton in one place — the southern part of the United States — has engaged the attention of manufacturers of cotton goods in all countries since the calamitous ruin of their business by the stoppage of supplies of raw cotton during the Civil War; but though there has been a considerable development in India, and a notable increase in production of good qualities in Egypt, the United States still supplies the world with 75 per cent of its cotton crop. Among the cotton-producing



THE COTTON FIBER MAGNIFIED

One pound of this fiber can be spun into a thread 100 miles long. An average picker will gather a hundred and fifty pounds a day, a fast picker as much as three hundred pounds.

countries are Brazil, the West Indies, Peru, China, Korea, Japan, Turkestan, West Africa, and the East Indies.

The first attempt to raise cotton in America was made in 1621 in Virginia. At no period in Colonial times was it a really important industry, Whitney's invention coming after the Revolution. Its wonderful growth during the past century and a quarter has contributed vastly to the wealth of America. A large share of New England's prosperity has come from its cotton mills, and, during the last thirty years or more, the establishment of mills in the home of cotton itself has increased the opportunities of that section by adding the

profits of manufacturing to those of growing the staple. Although it is now produced successfully in Virginia, Kentucky, Missouri, Florida, and Oklahoma, the region known as the "Great Cotton Belt" includes only the states of Texas, Georgia, Alabama, South Carolina, Mississippi, Arkansas, North Carolina, and Louisiana. The states of Texas, Georgia, and Alabama, taken together, produce more cotton than all the rest of the world outside this country. The conditions in our cotton belt as regards soil and climate are so nearly ideal that no other country can easily compete with us in this line. Before railroad connections were common in the far south, the Mississippi and its branches were the highways of cotton, and they all led to New Orleans. Here were storehouses for taking care of the crop, banks to advance money upon it, and vessels to transport it to other parts when sold. But the extension of the railroads diverted cotton from its old-time channels and other ports gradually absorbed much of the business that had made New Orleans rich and famous. More recently, however, the Gulf port has taken measures to win back its old-time prestige, and the Crescent City has now the largest and most finely equipped cotton warehouses in the world.

The division of the world's total cotton production

The United States consumes not much over one-third the cotton it produces. Under ordinary conditions, out of an average crop we should sell England upwards of three million bales, and the rest would be bought on the Continent and in Japan. The world's total yearly consumption of cotton is divided about as follows: the United States, 6,700,000 bales; the Continent, 6,000,000 bales; Great Britain, 4,300,000 bales; India, 1,700,000 bales; Japan and other countries, 2,200,000 bales. To weave into fabrics this vast amount of cotton requires the operation of more than 150 million spindles, over 36 million of them in the United States. Some idea of the immensity of the yearly crop of upwards of $3\frac{1}{4}$ million tons in this country

may be gained by imagining how much a handful of fluffy cotton would have to be multiplied to amount to this weight.

The impetus given American cotton planting through having for a time a monopoly of the Whitney gin for cleaning has never been lost. A parallel instance is seen in the great advantage derived by English textile mills from the genius of five Britons, — Hargreaves, Arkwright, Cartwright, Crompton, and Watt, — whose wonderful devices evolved power-weaving, and gave to English factories the tremendous start they obtained and have held up to the present time in the textile field.

The great cotton-spinning centers of the world

The manufacturing nations stand thus in the order of their cotton goods exports: (1) Great Britain, (2) the United States, (3) Germany, (4) India, (5) France. But the United States and India also import cotton goods largely, and Great Britain easily leads the world in this manufacture. Why is it that England has long held the foremost place in the world in the spinning and weaving of cotton? A great deal has been due to the natural advantages and unexcelled transportation facilities possessed by the Lancashire district, where the great English mills are concentrated; but there can be no doubt that the peculiar fitness of the climate for the work is one of the secrets of the success that Lancashire has attained. A certain amount of humidity is essential for cotton-spinning, so that the fibers may cling, while dampness is a disadvantage. If the climate of a cotton-spinning country does not furnish this humidity, it has to be produced artificially. Lancashire is the only district in which the requisite conditions are naturally present. Finally, the Lancashire operatives have so long been accustomed to following the mule-carriage, or changing the shuttles of a loom, that their skill is a valuable asset. This is in marked contrast with the labor conditions in this country, where in New England many untrained immigrants have invaded the mills, and in the South untrained work-people of native birth have been employed.

THE FIRST OF THE PROCESSES AT THE MILLS



As soon as a bale is unpacked, the tightly pressed cotton fiber is passed through a machine such as is shown here, called a "bale breaker," where spiked or fluted rollers pull the fibers into a mass of loose fluff.



Here we see the spiked roller tearing the mass of fiber apart, making it loose enough for the succeeding operations. The fiber is then carried away automatically to another room on a traveling lattice.

The cotton manufacturing industry in the United States

Though England, with all these advantages, has been able to retain the pre-eminence that was gained at an early period, the cotton manufacturing industry has expanded rapidly in the United States since the Civil War. New England continues to be the largest center, though its predominance has been lessened by the growth of the industry in the South. Today a larger number of spindles are concentrated within thirty miles of Providence than are to be found in any similar area anywhere else in the United States. Fall River is the largest center, with New Bedford, only twenty miles distant, not far behind. Other large centers in New England are Lowell, Lawrence, Manchester, Pawtucket, and Taunton. In the South the cotton manufacturing industry has grown up only within the past thirty years. The progress has been so rapid as at times to seriously threaten the supremacy of New England. Cotton factories have also sprung up in the middle Atlantic States, but here the conditions are not as favorable as in New England and the South. In the Philadelphia district small weaving establishments are particularly numerous; three-fourths of the mills in the United States that weave but do not spin are located in Pennsylvania, principally in Philadelphia. While the expansion of cotton manufacturing in Continental Europe during the last half century has been important — notably in Germany — England and the United States have remained far in the lead. Specialization has been carried further in the English mills than in other countries, yet the scale of production, particularly by the combination of spinning and weaving, is fully as large in America, and in the production of large quantities of standardized goods, America is rivaled only by the spinning mills of England.

The manufacture of cotton is divided into two well-marked series of processes — spinning and weaving. We must now trace the cotton, after its arrival in the form of compressed bales at the cotton

mill, through the series of processes of extraordinary complexity known as spinning. The first operations are the breaking of the bales and mixing of the cottons they contain. As the bales include various qualities of cotton, it is necessary that they should be well mixed so as to secure blending and uniformity, otherwise the manufactured material would not be reliable throughout. The best and worst cottons are not blended, but only those which fairly approximate to each other. The mixing is done generally by a machine known as the "cotton puller."

How the cotton is cleaned and carried away on a current of air

The cotton is then "opened" out so as to be cleansed of any seed, leaf, or dirt that it may have retained. It is fed through a machine to a beater, which frees it of its impurities, and the cleaned cotton is borne away on an air-current produced by a powerful fan, and plastered on a sieve cylinder through which the air passes. Having gone through this cleansing process more than once, the cotton is passed between compression-rollers and formed into a roll, or lap. This opening and cleaning process is sometimes repeated through a "scutcher" — another beating machine — and a thicker lap of more perfectly cleansed cotton is formed into a large sheet.

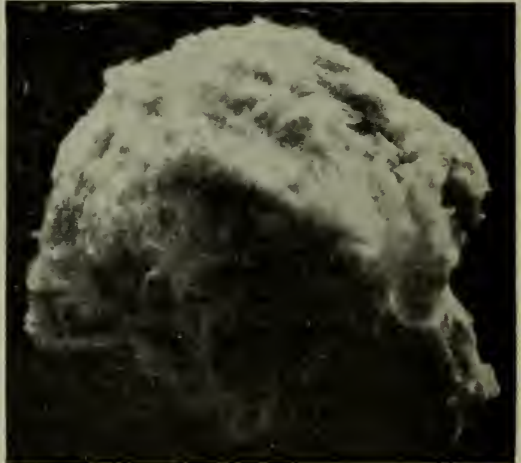
Carding now begins. The purposes for which the cotton is passed through the carding-engine are — to complete the process of cleaning, to disentangle the fibers from knots so that they may become parallel, to extract the broken fibers, and to deliver the cleansed cotton as a loose rope, or "sliver," ready for it to go to the "drawing-frame."

The drawing-frame is a machine for improving the sliver, by making its fibers parallel and its thickness and strength uniform. Six slivers are put into the machine, and are drawn into one; and this is repeated, usually three times, till a rope of untwisted cotton has been formed of even strength. It is now ready for what is called "slubbing" — that is, taking a passage through machinery which attenu-

CLEANING THE COTTON FOR SPINNING



The cotton fiber is passed through a machine known as an "opener," which further loosens it, clears it of impurities, and rolls it into a sheet. The cylinders are perforated, so that the dirt may fall through.



The work of cleaning is continued by another machine called a "scutcher," named from an old word meaning to beat or roll out. These two pictures show cotton fiber before and after the scutching process.

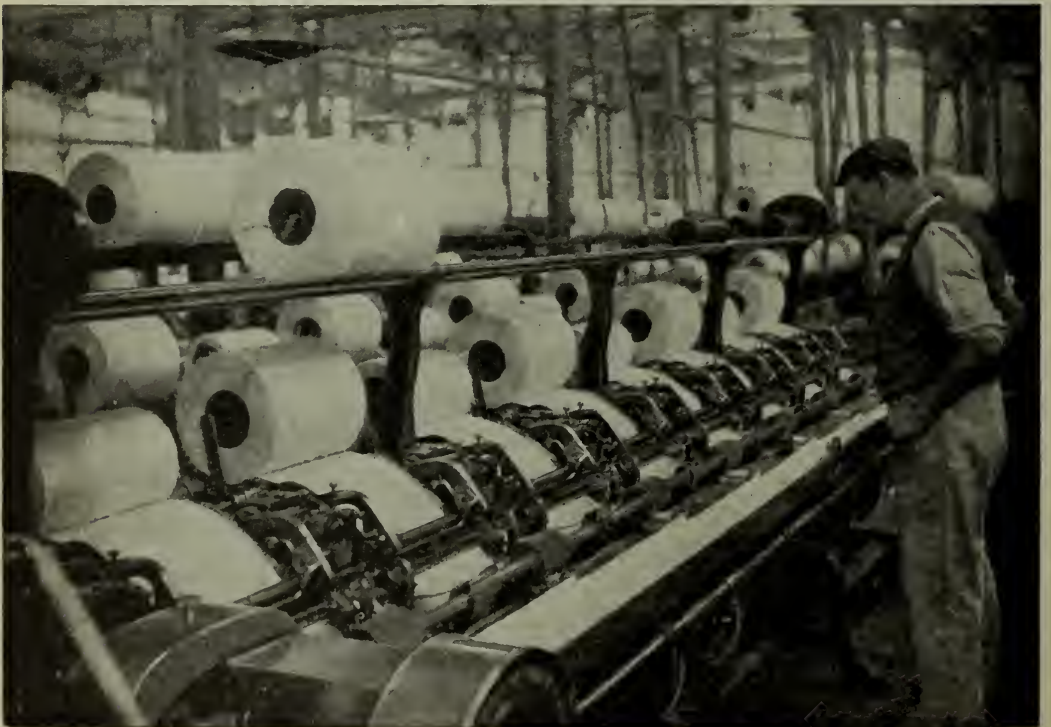


Here is the scutcher at work. It is something like an opener, and not only cleans but continues the rolling out of the cotton fiber until it is in a sheet of a uniform thickness ready for the next machine.

A COMB WITH OVER SEVEN MILLIONS OF TEETH



The fiber is passed through this carding-machine and made into a rope, called a "sliver." The machine really combs the cotton fibers by means of tiny teeth, of which one machine may have seven million.



A number of slivers are run together in a combing-machine, such as is shown here, which further insures the parallel arrangement of the cotton fibers and mixes them so that all are of uniform length.

GIRLS WIND THE COTTON ON THE BOBBINS

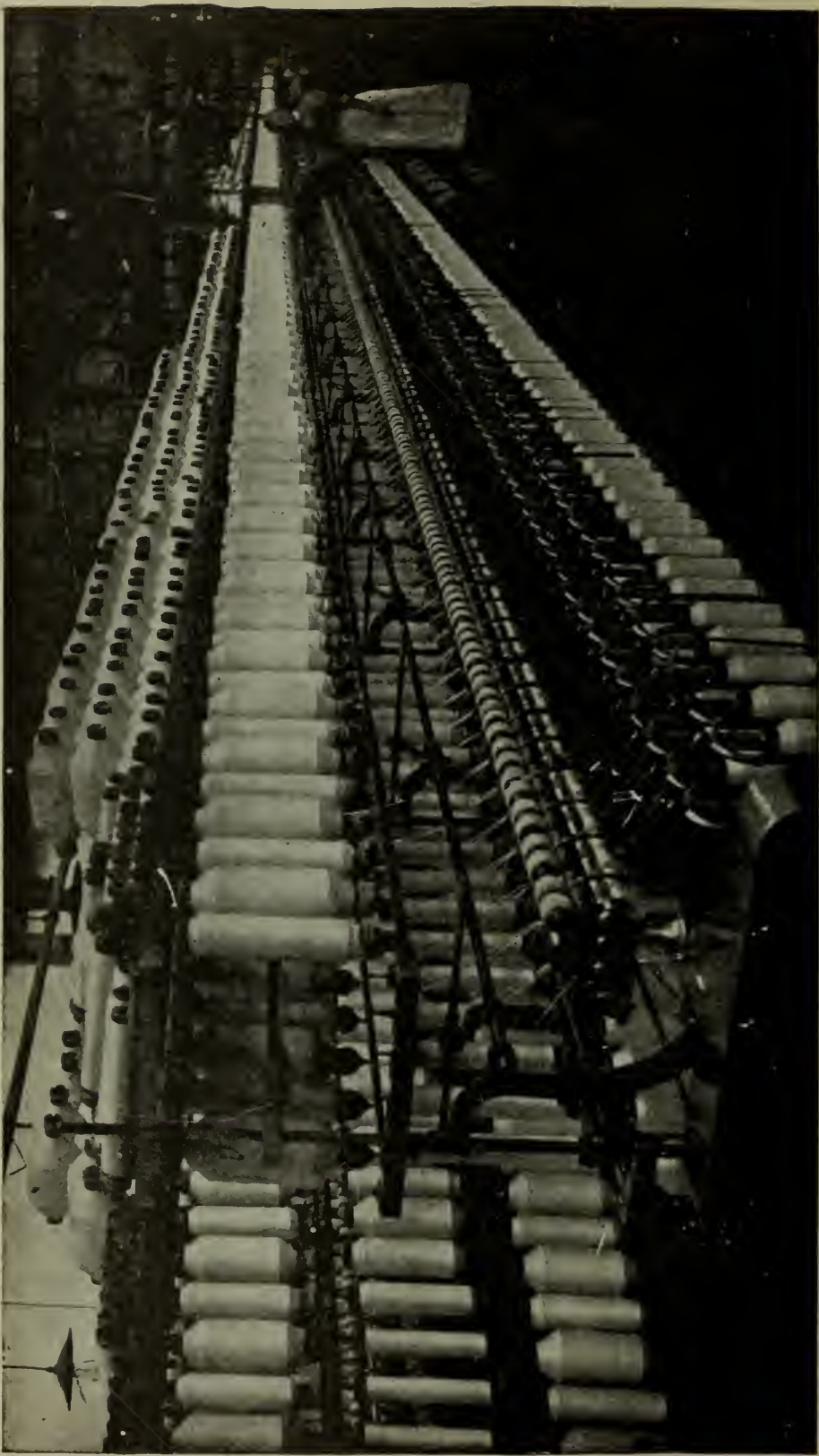


The united slivers are now passed through the drawing-machine, which draws out the band to the width of a single sliver. The strands are thus made uniform in thickness and the fibers more parallel.



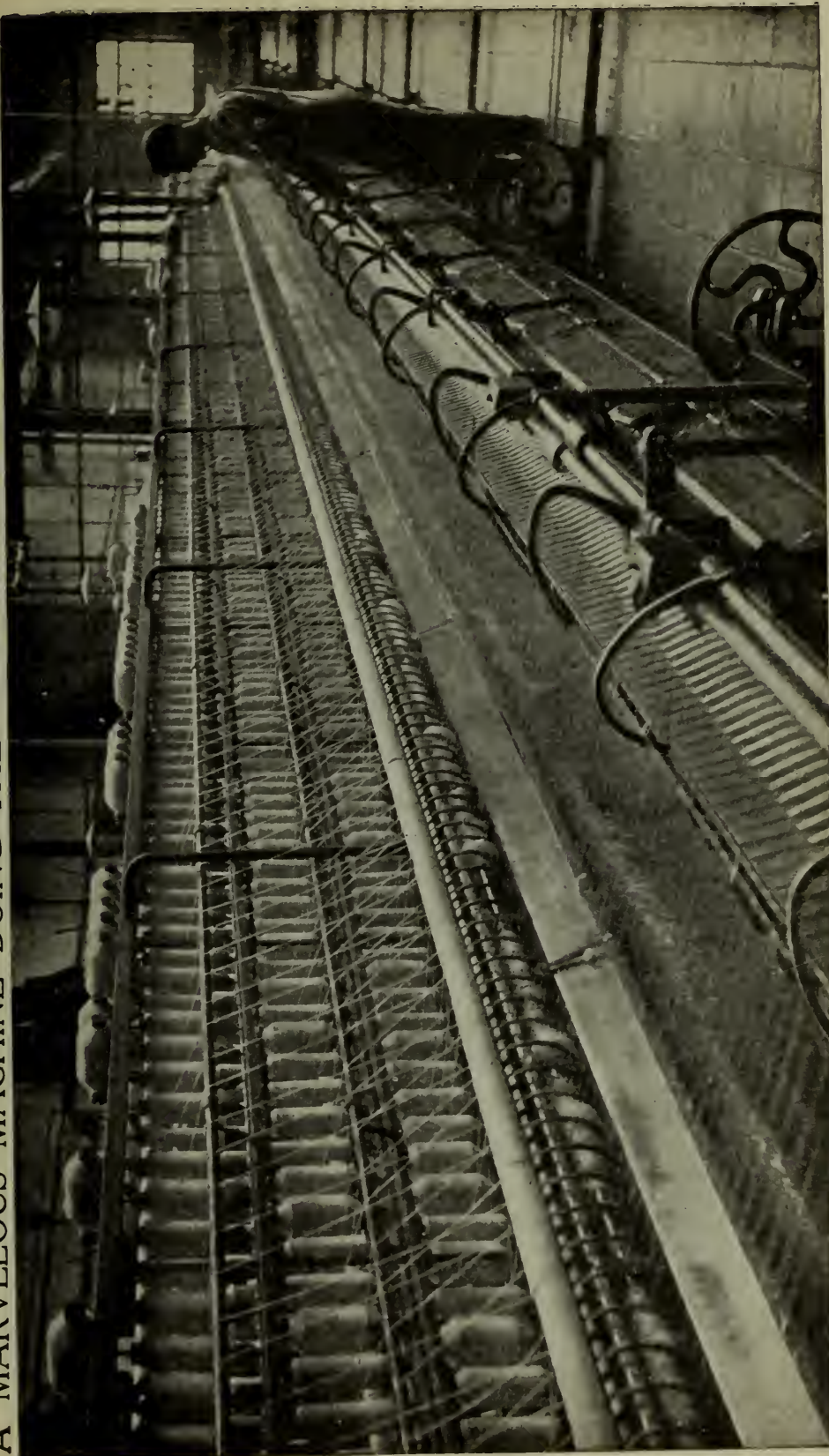
The next process is known as "slubbing." The cotton is brought in cans from the drawing-machine, and passed through rollers which draw the strands out further, twist them slightly and wind them on bobbins.

A MILLION YARDS OF COTTON ROUND A THOUSAND BOBBINS



One of the most wonderful sights in the world is the scene in this photograph. In this machine, called a "roving-frame," millions of yards of cotton fiber are constantly rushing between rollers and being wound upon thousands of bobbins. This is the last process before the actual spinning begins.

A MARVELOUS MACHINE DOING THE WORK OF FOUR THOUSAND WOMEN



No more wonderful machine has ever been invented by man than the spinning-mule. It almost seems to have brains as it works, and, tended by only a man and two boys, it can spin as much cotton as four thousand women could do in the olden days. A single machine such as the one shown in the picture has as many as thirteen hundred spindles, and is capable of spinning and winding four thousand miles of thread in one day. It spins the very best and finest of yarns.

ates the thread and gives it a strengthening twist, a process repeated and extended in the "intermediate" and "roving" frames. Some of the most delicate mechanical improvements in spinning machinery have been concerned with the attenuation and twisting of the strands of cotton and the winding of them on bobbins, for the "rovings," as they are called, remain very weak at this stage.

The many purposes for which the cotton thread may be used

The rovings are now ready to be spun into thread. This is accomplished either on a spinning-mule — an invention by Samuel Crompton in 1779, which remains in principle as he left it, but has been improved in detail by innumerable successors — or on a ring frame, which is an improvement on Arkwright's machine. First the rovings are drawn out to a greater attenuation in the mule — say, to nine times their former length — and are given twists according to the fineness of the yarn — say, twenty-four per inch. The ring-frame is of comparatively simple formation, spins continuously, and is intrusted to women and girls for the production of the less fine yarns, while the mule has extremely complicated mechanism, with intermittent working time, owing to a reversing action, and its manipulation needs skilled workers.

The thread is now ready for use if it is to be worked into the weft in weaving; that is, into the set of threads which in a piece of cloth run from side to side. But if it is to be used for the threads that form the warp — that is, run lengthways of the piece — it is wound on a large wooden beam, probably four hundred threads being laid side by side and sized with a strengthening and preserving paste, before being transferred to the weaving-loom.

If the yarn is to be used for something more elaborate than plain cloth, it may have to be bleached and dyed; and to facilitate these processes it is reeled into hanks, forty yards long, and the hanks are "bundled" by pressure into packages, usually of ten pounds' weight.

The processes in the making of cotton cloth of many kinds

Sewing-thread is not spun directly from the yarn, but several separate threads — generally four — are brought together and twisted into a sewing-thread before being polished and wound on spools.

The weaving process is common to all plain fabrics, whether the patterns are plain or fancy, or the Jacquard loom is used. Goods go from the manufacturer to the bleacher, from the bleacher to the dyer, and from the dyer to the printer and finisher.

The bleaching process alone involves half a dozen treatments. First the cloth is singed to remove projecting filaments, and then washed; boiled with lime for eight hours, and washed; "soured" with sulphuric acid, and washed; boiled with soda ash for from six to twelve hours, and washed; passed through a solution of bleaching powder, and washed. Before cotton goods can be dyed they are as a rule passed through a solution of mineral salts with the effect of causing the dye to adhere to the fiber. Dyeing and calico-printing are chiefly carried on in this country in the New England district.

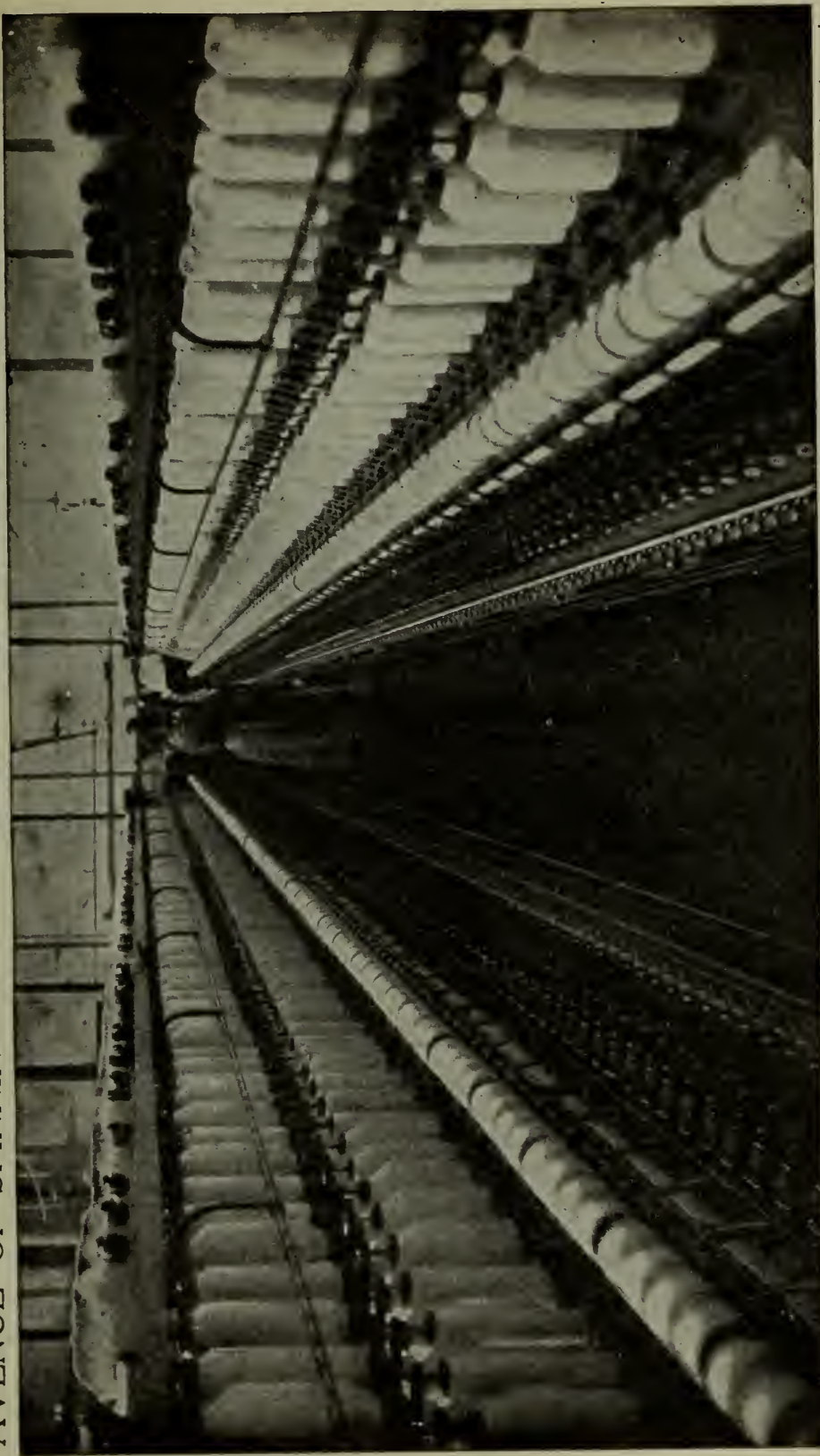
Cotton has the questionable quality of lending itself to imitation of other materials, so that woollen, silk, and linen goods can be and are alike suggested in cotton fabrics, and the fiber is also used in combination with these other materials. Unmixed, it is woven into an enormous variety of goods, from plain sheeting to embroidery.

The amazing variety of style and design in the cottons of the world

The common divisions of the fabrics are: plain goods, such as printed cloth and sheetings; twills, with diagonal warp threads; sateen, fancy cloth, and Jacquard fabrics.

The names given to different types of cotton goods — pure cotton, imitation, or part cotton — are legion, and illustrate the amazing variety of style and design. As examples may be mentioned baize, bandana, bombazine, brocade, calico, cambric,

AVENUE OF SPINNING COTTON IN ONE OF ENGLAND'S GREATEST MILLS



In the spinning-mule shown on page 277, the action of the machine is intermittent, the parts not working constantly in one direction. But in the ring spinning-frame, which is shown on this page, the spinning goes on continuously without any stoppage or change of direction. This machine spins the strongest yarns.

canvas, chintz, corduroy, crape, cretonne, denim, dimity, drill, duck, gauze, gingham, moleskin, mull, muslin, nankeen, print, rep, twill, velveteen, shirting, sheeting, Oxford, mercerized cloth, lace, lace curtains, piqué, Bedford cord, grenadine, zephyr, silesia, sateen, hollandette, lawn, batiste, serge, huckaback, galloon, cheese-cloth, mosquito netting, khaki, and last-
ing.

Cotton may be spun into an almost incredible thinness. A pound's weight of raw fiber can be subjected to all the processes of preparation that have been barely enumerated here, and then drawn out into a thread 84,000 yards long!

The fate of the Englishmen who turned cotton into gold

The story of the improvement of the machinery by which cotton is prepared for man's use is a particularly sad one, as it covers the days when men believed that machinery ruinously lessened the demand for labor. The use of cotton goods at all in England was for a time interdicted in the interest of the wool trade, the penalty for wearing calico being \$25, *to be paid to the informer*. When the manufacture first gained a footing in the land the warp was by law confined to linen yarn.

As invention became stimulated suspicion and persecution grew with it. Thus John Kay, the maker of the flying shuttle, was driven from the country and died in poverty abroad. Lewis Paul, who originated the principle of spinning by rollers, does not seem to have profited much by his ingenuity. James Hargreaves, the inventor of the "spinning jenny" — which, by the way, could deal with cotton only in a state of roving — was obliged to flee from Lancashire and restart business in Nottingham. The only prosperous inventor was Richard Arkwright, the Preston barber, who invented the "water frame" spinning machine — so called because it was worked by water — and he removed from Lancashire to Derbyshire before he established the business which made his fortune. Samuel Crompton, whose spinning "mule" — a combination of the machines of Hargreaves and Ark-

wright — was the greatest of all spinning machinery inventions, lived in old age on the subscriptions of sympathetic friends, after having lost the £5000 with which the British government recognized his merits as an inventor.

The industry built up by British genius adapted to American conditions

Richard Roberts of Manchester, who made the "mule" self-acting; Edmund Cartwright, who introduced the powerloom, and was awarded £10,000 by the government because he impoverished himself by his experiments; and Joshua Heilman, an Alsatian who invented the comber, and died soon after he attained success, have an honorable place in the history of the improvement of the complex machinery for the most complicated of manufactures.

With the exceptions of Whitney and Heilman, the technique of cotton spinning and weaving was revolutionized by English inventors. But their inventions, remarkable as they were, were only the beginnings of improvements which have continued to the present time. In these improvements the American manufacturers have played an important part. Except for occasional developments in other countries, England and America have made nearly all the important inventions in cotton machinery since 1860. The Germans have made a notable contribution by developing the synthetic dye-stuffs, and it should not be forgotten that the entire western world is indebted to Paris for original designs to be used in weaving and printing, as well as in the lace and embroidery industries. The English inventions have been more in the direction of the improvement of the finer processes, while the Americans have developed machines suited to the peculiar conditions with which they were confronted, especially those machines which permit the utilization of the most available supply of labor, the unskilled immigrant. It is to this development, perhaps far more than to anything else, that the progress of cotton manufacture in the United States has been due.

THE WINDING OF THE THREAD FOR THE WEAVER



When the cotton fiber has been spun it is called "yarn." The spools of yarn, known as "cops," are taken from the spinning-mule, and the thread is wound on bobbins by a machine like this, ready for weaving.



The bobbins are now arranged on large frames called "creels," and a warping-machine takes all the threads from the bobbins and winds them side by side in regular order upon a roller as shown here.

THE PREPARATION OF THE WARP FOR THE LOOM



The threads of the warp are put in a bath of liquid-size to strengthen them, passing for this purpose through a slashing machine. Then the warp threads pass over hot cylinders, which thoroughly dry them.



The warp, which is the foundation of the cloth into which the weft, or cross-threads, will be woven, is taken to a drawing-in frame, where a man passes the threads through a guiding-frame, ready for the loom.

WEAVING LOVELY PATTERNS ON THE LOOM



This is the Jacquard loom, which enables an ordinary worker to weave the most beautiful patterns. The perforated drum at the top produces the pattern, in much the same way as the perforated ribbon plays the pianola. The inventor of this loom was nearly killed by his infuriated fellow-workmen.

IN ENGLAND'S LARGEST WEAVING MILL

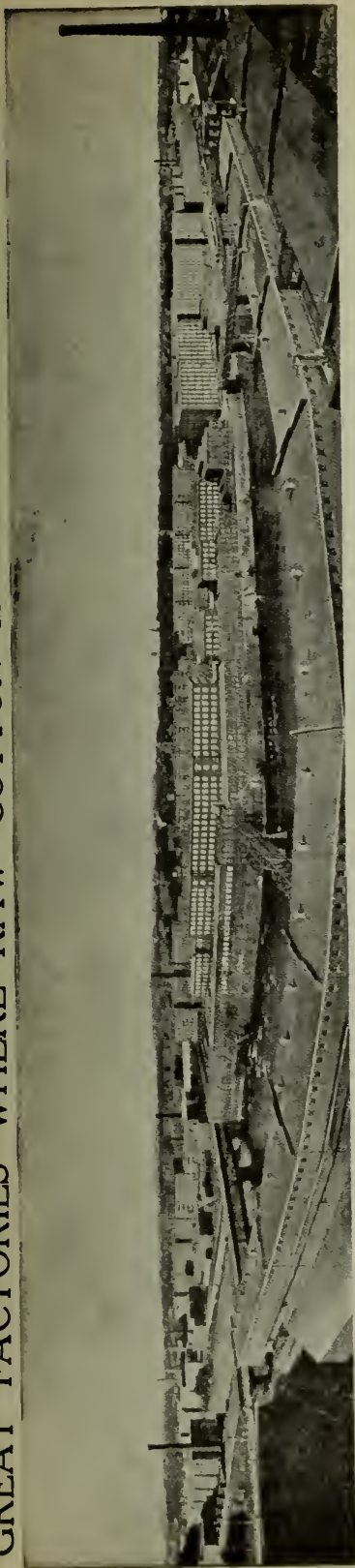


This shows what a weaving-shed is like. It is inside the largest weaving factory in England, that of Horrockses, Crewdson, & Co., at Preston, and the looms are seen stretching away in the distance.

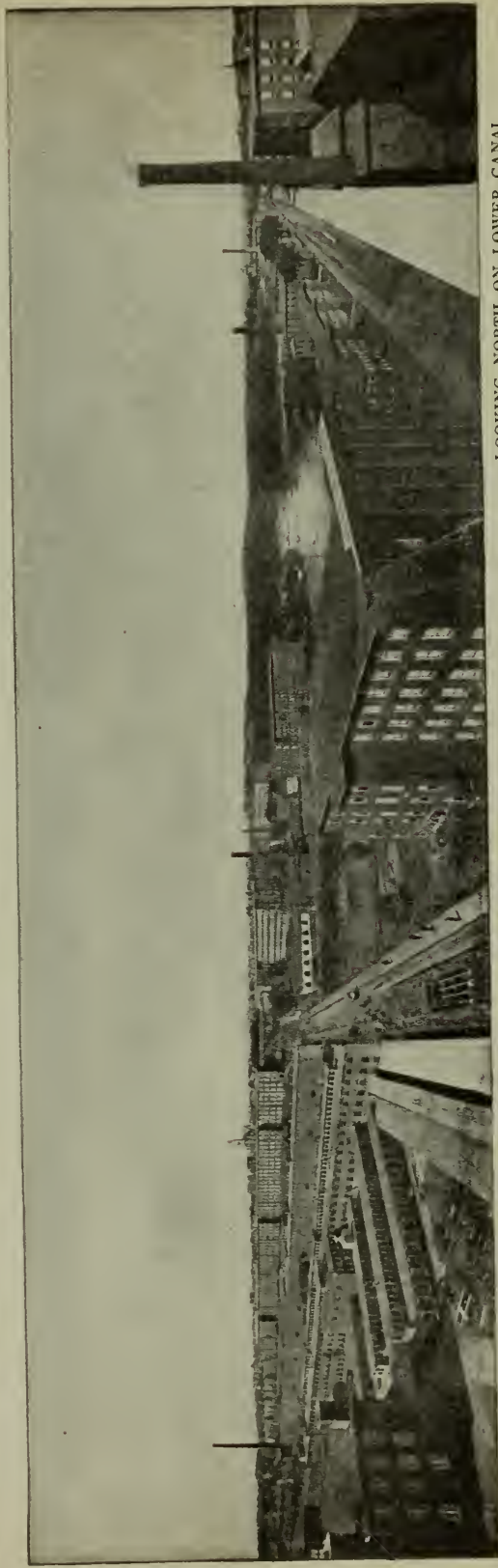


Sheeting is made on very large looms like the one in this picture. As the cloth is woven it is wound first on a roller in front of the loom, and is then taken away to be folded elsewhere by machinery.

GREAT FACTORIES WHERE RAW COTTON IS CONVERTED INTO CLOTH



MILLS ON THE EAST BANK



MILLS ON THE WEST BANK

LOOKING NORTH ON LOWER CANAL

Mills of the Amoskeag Manufacturing Co. on the east and west banks of the Merrimac River at Manchester, N. H., where more than 15,000 people are employed in the manufacture of cotton and woolen goods. Here 620,000 spindles and 22,700 looms consume annually 55,000,000 pounds of cotton. The annual output is over 1,600,000 bags and nearly 5,000,000 yards of cotton cloth.

America leads in consumption of raw material, England in spindles

Though England employs twice as many spindles, the American mills consume more cotton than those of England. This is explained by the larger production of fine yarns in England and more extensive use of the mule, on which the output per spindle is about two-thirds of that of the ring frame. In the United States the manufacture of fine yarns has only recently begun to develop; the bulk of our output is still the coarse and medium grades of plain goods. Consequently our imports are mostly of the fine and fancy grades, of high quality or of special design. Our chief exports at present are heavy gray goods of plain texture such as our mills can make in large quantities at low labor cost.

The world's annual production of raw cotton—that is, the lint as it arrives in bales ready for the manufacturer to begin his long series of operations—reaches a weight of about five million tons. Perhaps one-third of this does not leave the country where it is grown, for most of the cotton-growing regions have some cotton manufactures, but the transportation and re-transportation of the rest—and, indeed, of the products of the whole of the world's cotton-fields and spindles and looms—furnishes one of the most wonderful examples of universal interchange of goods that modern commerce can show. The steel goods of Germany, the woolen wear of England, the leather-made products of America, the fancy dress-goods of France, the silks of the Orient, the wheat of the Canadian prairie, the fruits of the West Indies, California and the Levant travel far, and reach many races living under varied conditions, but the width of their dissemination, with, perhaps, the single exception of the knife, is but limited compared with that of the roll of cotton cloth. The range of the cotton trade is that of man's clothing. It is only the naked who are exempt from its use.

Note, too, how it interweaves the lives of all the diversities of mankind. The merry negro Americanized on the cotton

fields of South Carolina, Georgia, or Florida, grows the flossy snow that gives work first to the hardy sailor, and then to the keen-witted "operative" of the mills, and through his machinery, to the engineering centers of the world. All unaware of its origin in the "Sunny South," the British farmer buys, by binding agreement with his landlord, so much "cake" for his cattle that the fields of England may be manured by the cotton-seed of another hemisphere. The fisherman of Quiberon Bay is brought up to Paris to warn the French government that in making its tariff arrangements it must not disturb the balance of trade that allows cheap oil from New Orleans to be substituted for the olive-oil of Italy, otherwise his trade in canned fish delicacies will be ruined.

This forward flow of cotton products over the face of the civilized world is followed by a backward flow of enhanced value from the manufacturing centers over the earth, civilized and uncivilized; and the negro of the forest swamps of western Africa barter his humble wealth for a gaudy cheap cloth which has its origin in the organized labor of men of his own race transplanted by force a century ago across the dreaded ocean.

This expansive influence of the cotton plant, bringing all races into touch through its universal distribution, is balanced, however, by a restrictive influence. It is through the cotton trade that the modern factory system has been most completely, and deplorably, developed. The most distressing problems of modern civilization, especially in England—the overthrow of home life through the employment of women, the presence of the child in the whirring factory, the declining physique of the cooped-up worker, the mortality in infant life, the ravages of tuberculosis, the gray monotony of existence, the loss of the ideal of living in joy and not in pain—are all connected with this great industry more intimately than with any other, and naturally so at first, because it is the industry in which the use of machinery, mechanical order, organization to the last word of economical efficiency, have been perfected.

THE FIRST HUMAN FAMILIES

The Family as the Basis of Enduring Society
and the Inspiration of All That is Best in Man

THE ROCK ON WHICH GREAT NATIONS BUILD

THESE has been considerable dispute among men of science on the question whether the horde or the family was the original social unit. The matter has a practical significance.

If we can trace the evolution of the human family, we may be able to predict the course of its future development. This is, indeed, one of the chief services of science: as Auguste Comte said, we must see in order to foresee, and foresee in order to control. If it can be shown that man was primarily a gregarious creature, and that his rude, primitive, communal life was the factor which enabled him afterwards to form family groups, there is then a possibility that the highly organized state of the future might not retain the family as its base.

Already certain socialists of the extreme school are adopting the theory of the fundamental gregariousness of mankind, and trying to make it a political force. They hold that the family has merely been the temporary product of a particular stage of economic development, and that with the disappearance of private property the family also will vanish. It is predicted that all children will then be cared for by society as a whole, while men and women will be able to adopt or abandon married life as their fancy may dictate.

Wicked and mischievous as this idea is, it is not without some indirect support in a certain scientific theory of social origins now generally discredited but advanced by distinguished scientists between 1866 and 1880. They maintained that, as we look down the scale of civilization, the importance of the family diminishes and the power of the

tribe increases. This, some of these political revolutionists think, goes to prove that family life is not rooted deeply and permanently in human nature. More recent research, however, clearly shows that many famous men of science of the older generation were mistaken in regarding the horde as the original social form. The theory was mainly founded on the description of a tribe of natives in South Australia given by an English missionary, Lorimer Fison. Fison said that the tribe was divided into two classes; every man in each of these classes was the rightful husband of all women in the other class, and every woman in each class was the rightful wife of all men in the other class. The natives of Australia are savages of a very low type, and this description of their way of life was accepted as evidence that in primitive ages the relation between the men and women of the two classes was one of promiscuity, and that no family life existed.

Another very curious fact was brought forward in support of this view. About one-half of the savage races, scattered about the earth, have a strange system of maternal kinship; the children take their name from their mother, and reckon their relationship only through her, and sometimes the mother's brother exercises most of the rights and duties of the father. The maternal uncle sells his nieces in marriage, and avenges any wrong done to the children of his sister.

All this was thought to show that family life was originally unknown, and that the task of looking after the offspring of brief, animal-like, promiscuous intercourse fell chiefly on the woman, her brothers perhaps

helping her as regard for the tie of blood increased with the development of the mind of man. But it has already been proved that the notion of the promiscuity of the Australian native rests on an extraordinary misconception. In order to prevent the harmful effects of in-breeding, the Australian native, like nearly all races of savages, divides a tribe into two classes; men and women of one class may not marry among themselves, but only among members of the other class. This, it will be seen, is a very different thing from promiscuity; it is, indeed, completely opposed to what is called communal marriage. Instead of degrading man to the level of the beasts, it shows a practical wisdom of so high an order that it is utterly inexplicable how the primitive savage could have thought it out and reduced it to an almost universal practice.

Is the family rooted in marriage or marriage in the family?

This is one of the most mysterious things in the study of primitive society, and it will be necessary for us to examine it at some length when we discuss the science of marriage. The problem of maternal kinship, which has been used to confirm the theory of primitive promiscuity, is also a matter which can only be fully gone into in connection with the study of the later variations of human marriage. One important point in regard to it, however, must be touched on. At first glance it may seem as though we are taking facts in a wrong order in studying the family before we have dealt with the question of the institution of marriage. But marriage and family are intimately connected with each other: it is primarily and originally for the benefit of their children that men and women live together and grow into little social groups. Among many savages real conjugal life does not begin until a child is born, and thus we arrive at the conclusion that marriage is rooted in family rather than family in marriage. And if we can show that the family existed before the horde, it will be patent that we have discovered in the system of marriage the primary element of social life.

The family is the probable starting point of evolution

The opinion now held by most men of science is that "looking back far enough in the stream of time, and judging from the social habits of man as he now exists, the most probable view is that he aboriginally lived in small communities, each with a single wife, or, if powerful, with several, whom he jealously guarded against all other men."

If we study the other Primates, that is, the animals most like man, we shall find that they, too, live in small families. The gorilla builds a solitary nest for his mate, and at night crouches at the foot of the tree, guarding the female and young, in the nest above, from nocturnal attacks. The chimpanzee does the same thing; and in daytime one can see the parents sitting under a tree eating fruit and chattering, while the children swing in the branches over their heads. Less is known about the orang-utan, but he is not gregarious; and as he has been found with half-grown young in his care, it looks as if he were also a good parent.

In both the man-like apes and the human being there is a long period of infancy: the higher in the animal scale a young creature is, the more slowly its powers of body and mind are developed; and in the case of children it is comparatively late in their life before they are really able to provide for themselves.

The little child who led humanity along the path to civilization

So they have to be nurtured for a long period. Out of their helplessness is thus formed a bond between their parents. Out of sheltering love for the child the family is born. Out of the family, as we hope to show, are produced many of those institutions of society which mitigate the harsher struggle for existence. Does it not look as though the little child has, in a way, led humanity along the path of civilization?

It is easier to discover the reasons that kept man apart from man, in little scattered family groups, than it is to trace

AND A LITTLE CHILD SHALL LEAD THEM



"Out of sheltering love for the child the family is born. Out of the family come institutions of society which mitigate the harsher struggle for existence. Does it not look as though the little child has led humanity along the path to civilization?" This picture, by Mr. T. C. Gotch, is called "The Flag."

the socializing force which gradually drew men together into loose tribes. A savage, whose prey can be caught and killed without help, profits by living alone, especially if his quarry is much scattered, and is secured by stealthy approach or by lying in ambush. Gregariousness would be a positive disadvantage. Even at the present day there are savage peoples who live in separate families rather than in tribes, and most of these peoples belong to the very rudest races in the world. Sexual feelings, the instinctive love of children, and the customary attachment to relatives are the only ties that seem to keep them in any sort of union.

At last, then, we have reached a definite point from which we can follow, step by step, the evolution of the family systems of mankind. We have arrived among the lower hunters, who have scarcely made any important advance in social organization. As a rule, there are no marriage laws, in a legal sense, among them, as there is no tribal power, but marriage with a single wife usually obtains, owing perhaps to the approximately equal numbers of the sexes, rather than to any objection on the man's part to a plurality of wives.

Food consists of animals killed by the men, and roots and fruits gathered by the women. By reason of the crudeness of the lower hunters' weapons the resources of the land around the camp are quickly

exhausted, and the family has to wander about the world continually, urged by hunger and menaced by famine.

The husband is the ruler of the family; he buys his wife or gets her in exchange, and uses her as a slave. The children also are his property, even when they count relationship through the mother, and he frequently sells or exchanges them. His power over his offspring, however, ends when his daughter is handed over to another man, and when his son has passed into manhood. There is no system of inheritance in such a society, there being nothing to inherit, as a man's weapons are buried with him.

Sometimes, for the purposes of defense against a common foe, these scattered families now emerge for a while into small gangs without a chief. But war does not seem to have been the original force in drawing primitive man into larger groups. No doubt fights for the possession of women sometimes occurred between two or three males; and all the

members of a family may have sometimes combined in driving away a strange family which had invaded its hunting-ground. Yet it was not by quarreling but by rejoicing together over an abundance of food that men came to acquire feelings of wider fellowship. At present, the lower hunters are usually confined to the hard, bare places of the earth, where only for a brief season of the year nature is generous. In



THE PLAN OF A COMMUNAL HOME STILL EXISTING

This sketch was made of a homestead in Bosnia, and represents: 1, common dwelling house; 2, summer dwelling house; 3, granary; 4, goose house; 5, cow and goat house; 6, distillery; 7, well; 8, oven; 9, stables; 10, pig-sty; 11, corn loft; 12, piling; 13, corn; 14, orchard.

lands where conditions of life are easier, and game and fish are plentiful, are found the higher hunters. They are more numerous than the lower hunters, because larger supplies of food have enabled them to expand; and on the spots along the coast, where their resources seldom fail, they have gathered into settlements. The household is still the strongest bond of society, but on the household is now built the primitive village community, and

clan or tribe. The position of women, however, is still very low. Wives are bought, and treated as slaves. Daughters are a source of profit, and sons of power. For the era of warfare now begins: abundance of food leads to the increase of population; there are rich hunting-grounds and fishing-grounds to be won, and slaves are becoming useful. And then, with permanence of settlement, ancestor-worship develops; and this often makes the male



THE MOTHER TO BE — FROM THE PAINTING "WHERE SHALL WISDOM BE FOUND?" By Mrs. Young Hunter

these communities are linked into a loose tribe.

In this stage of culture the chief elements of human society have been evolved, but the family remains somewhat rudimentary. Husbands and wives have both reached a higher degree of skill in industry, and things are made not only for family use but for exchange. In many cases the family has lost its special hunting-ground, the territory now being the property of the

a much more important member of the family than the female.

Out of the chase of the higher hunters is evolved the tending of flocks and herds. As this is always, like hunting, the business of the men, the woman at first continues in a low position in the family. She is still bought; and as a man's herds increase he is able to buy more wives. It is among pastoral peoples that polygamy begins widely to obtain. Large families become

very profitable to men with great flocks and herds: the boys are cheap herdsmen, and the girls are very serviceable in the house. The invention of the finer domestic crafts increases the economic value of woman. In some pastoral tribes a settlement is made upon her, and if her married life is unhappy her kinsmen gladly receive her back. For the family has now gained a remarkable steadiness and strength. In its herds or flocks it has a personal property of very high importance. Petty but incessant tribal feuds over pasturage rights and the theft of cattle interfere with the development of political institutions, but,

on the alluvial soil of great rivers, and began to till the fruitful earth. Nearly all the work of farming fell on the women and girls — the men and older boys having to tend and guard the herds. Some writers think that woman was the discoverer as well as the agent in the development of primitive tillage. This is only a probability, but if woman was the author of the mighty, civilizing power of agriculture, she has been indirectly rewarded by the general improvement which her work effected in the organization of the family. By carrying on both farming and stock-breeding, the peoples living in well-watered



A HALL OF ANCESTOR-WORSHIP IN CHINA

besides making home life more stable and larger, and linking closer together the older and younger generations, the acquisition of property stimulates man to undertake a more effective advance towards civilization.

Some races have never learned the art of the herdsman, but, while still hunting and fishing in settled communities, have turned to farming. This has happened in certain luxuriant regions in tropical or semi-tropical climates. The most progressive peoples, however, took a less abrupt and broader path, leading up to a wider prospect. Wandering slowly in large and stable families, in search of moist, rich pasturages for their herds, they settled

lands obtained ample and regular supplies of food. Population, therefore, increased at an extraordinary rate; the great patriarchal family was developed, and the foundations of modern civilization were laid.

The rural family community is one of the most important of social forms and one of the widest spread. In ancient time it existed, with modifications, from China to Britain. In the Orient it has survived great political revolutions and foreign conquests, and it has adapted itself to urban conditions and industries; it is the force behind ancestor-worship, and, as such, is largely responsible for the marvelous expansion of the multitudinous Chinese race.

The foundations of modern civilization laid in the family community

In Europe the great family community has now been generally destroyed by the forces which have built up our modern industrial civilization. Yet in the Balkan States, where for centuries civil law and political institutions were wiped out by the Turkish invasion, the Southern Slavs have preserved the chief element of national life by holding firmly to the old traditions of family fellowship. Some writers of authority regard the type of society founded on the communal family as that which is most conducive to the happiness of mankind; so it may be worth while describing the family community as it still exists in the Balkans at the present day. A plan of a typical home is shown on page 290.

It is a very big family, including cousins and more distant relatives, and the management is in the hands of the oldest member. His authority is great, but it is used in a fatherly way: he represents the family in the village council. All the property is held in common, and all the work is done in common. The men perform the hardest labor in the fields, such as plowing, reaping, and digging; the women do the housework, and make clothes, and help in sowing and harvesting; the children tend the flocks. Save for a few iron tools and machines and utensils, the family does not buy anything. Provisions, clothes, boots, bedding, wooden ware, pottery, are all produced by the community, and their houses are built by the men.

The family organization that prevailed for many centuries in Europe

The work is mapped out, and the workers selected by the assembled family. All income and personal gains are paid into a common fund, which is not divided equally, but given out to members according to their necessities. When, for instance, one of the family marries, the community bears all the expenses. If a member leaves the family, he loses his rights; but if the community grows too numerous a division is generally agreed to, and the property is split up.

Undoubtedly, in a family organization of this kind, most of the social problems of the present day are solved, except perhaps the problem of progress; and its extraordinary strength is shown by the fact that it survived a long period of war, defeat, and oppression. Indeed, it lasted, in various modified forms, throughout a large part of Europe until about the end of the Middle Ages. In the great rural tracts of Russia, Hungary and Austria it endured long into the modern era.

Growth of the great family in the East and its break-up in the West

Only in Japan and China, however, has the great family developed from a communal life founded on agriculture into an industrial organization. In China, all the earnings of near kinsfolk flow into a common chest, which is managed by the patriarch. In western Europe, through a variety of causes, religious, political and economic, the great family has broken up, and returned to the primitive grouping of two parents and their children.

Before discussing the small modern family it will be instructive to notice a system of family coöperation found in Italy, adapted from the ancient rural family community, with a greater division of labor and freedom of life. In one case the family owned a hotel, managed by the elder brother. In a farm close by lived a sister, who cultivated the common land. One brother was a baker, working in the annex of the hotel; two more brothers, a blacksmith and a carpenter, lived in workshops; and two others, a military doctor and an officer, in distant towns. The six brothers and sister had a common purse, and shared the income and expenditure. This seems to be a successful attempt, under modern conditions, to preserve the strength derived from family communism, while allowing the individual members to branch out on independent careers. It requires, however, the possession of family property in the first instance, or considerable contributions to the family fund; and a spirit of self-sacrifice must animate the workers in the group when there are some members who bring in nothing to the common fund.

The modern workman who goes out to win a living as did the hunter once

As a rule, the small modern family is not held together, as in earlier times, by the possession of common land. With the advance of industrialism, the social significance of land-holding decreases, even in Europe; and in America any form of attachment to the soil is now nearly unknown. The majority of men today face life in circumstances quaintly resembling those in which their remote ancestor, the wandering hunter, went forth to win a living and a wife. With a few tools, perhaps, and some skill and knowledge, they go out into the industrial or commercial world, sometimes with their father at hand to guide them, but often alone and adventurous. When they are ready to marry, they do not have to obtain a wife by purchase, or work for years for the father of the young lady, but marriage still remains an expensive matter. Not infrequently in our great cities, the resemblance between the modern workman and the primitive hunter is still more drawn out. He moves away from his home and settles in a strange district near to the spot where he gains his livelihood; and, if he is very poor or unfortunate, his wife — like the wife of the savage — may have to work outside her incomparable sphere.

The misfortune of ever transplanting the mother from her natural sphere

The degradation of the mother has a deplorable effect on the health and training of the children. The organizing influences of the household are destroyed, and there is left that sorry piece of social wreckage, the unstable family of the modern era. Families of this unstable type appeared in large numbers in England on the breaking up of village communities and establishment of private property in land. In the sixteenth century farming went out of fashion, and a great deal of the country was converted into pasturage for sheep. There was, again, a widespread shifting in the industrial grouping of the people when steam machinery was generally applied to manufacture.

The root from which nearly all the disorders of modern society spring

Undoubtedly the great industrial revolution had a disastrous social effect; it did more than any political force has done to create the unstable family — the root from which nearly all the disorders of modern society spring. It led to the establishment of free contract as the normal relation between individuals, and broke down the ties of personal fealty and status fixed by custom, which formerly assured to every one his place in the social fabric. A general loosening up of social relations resulted; and many men and women, unable to find or to make a place for themselves in the new order, became disconnected atoms in the life of the community, bound by no ties of duty or responsibility, and often incapable even of self-maintenance. In every industrial nation many such are still found. Poor-laws have been framed to remove the symptoms of the disease, but they cannot revive the traditions of settled family life to the loss of which so many of our social maladies are due.

The strength of the tie of family love which supports the modern state

Apparently these evils of family instability are a part of the price we must pay for liberty and progress. But the evil must be kept within bounds if the foundation of civilization itself is not to be swept away. And there are many indications that a large part of our troubles are connected with the transitional state — growing pains, as it were — and that family life is successfully readjusting itself to the changed order of things. Even the high and rising divorce rate of the United States may indicate that the ideals of family life are higher, and not lower, than in other countries and at earlier times.

One important form of coöperation still prevails in modern family life: this relates to the spending of the family income. The income may be produced by different members of the family working at diverse occupations, and each member may have a share for personal use, but in a working-class family the larger part of it is treated as a common fund. This part will nor-

mally be under the control of the mother, who looks after the home and the younger children. It is perhaps unfortunate that under the modern factory system the economically productive work of the wife and mother must often be done outside of the home, for a money wage, and not, as earlier, inside of it and directly for the family. Though the burden of household duties has thus been reduced, and the comforts and conveniences of the home greatly increased, the effect of the change in weakening family ties cannot be gainsaid. But when there are no young children in the home, such outside work, unless it prevents the birth of children, is not necessarily an evil, and may be a desirable means of personal expression.

The extent of the employment of wives and mothers in industry

The extent of the employment of wives and mothers in industry is somewhat uncertain. About one married woman out of eighteen in the United States is "gainfully employed," but of course a large proportion of these have no children, and a considerable number do not work outside their homes. The proportion of wives so employed seems to be slightly on the increase in this country, but in England, where the proportion is twice as great, it is thought to be declining.

Those external circumstances like laws, social customs, and economic conditions, which once held families closely knit together, are certainly weaker now than formerly. But can an ideal family life be based upon constraint? The modern world, and preëminently America, thinks not. We have gone farther than other modern nations in permitting divorce, as we have gone very much farther in leaving our young people free to choose their own society and to select their partners in the marriage relation. Possibly this procedure is not yet past the experimental stage, but the ideal certainly is not to have weak and shifting family connections, but to have the family upon the solid rock of congeniality, community of spiritual interests, and genuine affection.

More independent spirit of the younger members of the family

Similar statements apply to the relation of parents and children. Materially speaking, they are much less necessary to each other than formerly. Children are now rarely an economic asset to their parents, as they were until recent times. And from the side of the child, too, after infancy, the family relation means less. It is in the school, on the playground, in the workshop, even on the street, that children now acquire most of their knowledge and skill with which they make their way in life. Hence it is but natural for them to display a more independent spirit than the young members of the old family community possessed. When, however, the home-life of modern children is sound and happy, they learn to combine with their regard for personal liberty the sweeter feelings of loving duty and affectionate coöperation. When they go out into the world, they are bound to the family by loyalty and sentiment rather than by the ties of material interests.

No doubt the family arose originally out of the exigencies of the material struggle for existence, and developed largely in response to industrial needs; but it is more and more rising to a higher place. As the material bond loosens it is being replaced by higher and finer feelings, the highest and finest of which human beings are capable. Future alterations in law and in the conditions of obtaining a living may affect, but they cannot destroy it. For the modern family, and above all the American family, is based on love, not on *convenience*. The relations between man and wife, between children who grow up together, and between parents and children — when these relations are voluntary — make an irresistible appeal to all that is best in human nature. The family will continue to be the great agency in developing character, the primary training-school for inculcating the social virtues, and teaching men the high value of mutual aid and coöperation.

Because the State rests upon the family, it is secure.

AMUNDSEN, DISCOVERER OF SOUTH POLE



THE FAMOUS NORWEGIAN EXPLORER ROALD AMUNDSEN, WITH HIS VESSEL, "THE FRAM," WHICH TOOK HIM TO THE ANTARCTIC SEAS

EXPLORERS

DUKE OF THE ABRUZZI—THE ADVENTUROUS SON OF A KING
 ROALD AMUNDSEN—DISCOVERER OF THE SOUTH POLE

DUKE OF THE ABRUZZI
 The Adventurous Son of a King

THE Duke of the Abruzzi, Prince Luigi Amadeo Giuseppe Maria Ferdinando Francesco, began his life of adventure in his cradle. At his birth, in Madrid on January 29, 1873, he was the son of a reigning king; a few days afterwards he was merely an obscure scion of the house of Savoy. His father, a son of Victor Emmanuel of Italy, was elected to the Spanish throne in 1870; but a republican revolution broke out, and King Amadeus abdicated in February, 1873, and, as Duke of Aosta, returned to Italy. His adventurous son was educated in the naval academy at Leghorn, where he distinguished himself by his modesty, his democratic manners and his brilliant ability. A tall, lightly built, and silent boy, he felt no attraction to the aristocratic life that opened out to him as nephew of the king of Italy. A life of mingled study and adventure was what he aimed at, and while still a boy he distinguished himself by scaling the hitherto unconquered peaks of the *Demoiselles Anglaises* on the Mont Blanc range. The heights were called "The English Girls" because of their coldness and inaccessibility.

After finishing his studies as a naval officer, the duke disappeared from Italian society and completed his education in his own way by a tour round the world. On his return he was still invisible to courtiers and clubmen; his days were spent in incessant study and excursions in the Alps. The real fever of adventure was now stirring in his blood, and he was carefully planning his first great achievement.

WILLIAM BAFFIN—THE GREATEST POLAR SEAMAN OF ELIZABETHAN TIMES
 VASCO DE BALBOA—THE MAN WHO FIRST TRAVELED ACROSS AMERICA

On the borders of Canada and Alaska there is an Arctic mountain, St. Elias (18,024 feet), one of the hardest climbs in the world. Many men had vainly attempted to climb it. The ice begins almost at its foot, and the high rocks are shrouded in eternal mist. The young duke, however, conquered the mountain before seeing it. Following the course of action he adopted afterwards in his polar and equatorial expeditions, he collected all available sources of information, studied them for some months, and then drew up a plan of campaign containing all the elements of success. He brought the science of strategy to bear upon the work of exploration, with the result that he ascended Mount St. Elias with remarkable ease in 1897. Then, having tasted the stern joy of arctic adventure, he resolved to plant the Italian flag on the North Pole.

After a long course of study at home, he reduced the problem to a scientific calculation, and went to Norway by a sealing-boat for the voyage. Here he made the mistake of purchasing a vessel that Nansen had rejected as being too lightly built to resist the pressure of the northern ice. The little *Stella Polare* was wrecked in the moving ice off the coast of Franz Josef's Archipelago, and the duke and his men had to camp out in tents. Had not a spiral movement of the icefield lifted the wrecked ship on to a solid plateau of ice, it is probable that none of the party would have survived. The disaster entirely upset the duke's plans, for he had provisioned the ship for five years, with the intention of taking it as far north as possible, and using it as the base of his operations.

Matters were further upset by an accident that happened to the duke while training his dogs for his sledge expeditions. One of his hands turned white and then black, and his fingers were so frost-bitten that the surgeon thought he would have to amputate the whole arm. The brave young explorer was compelled to remain for months in the shelter of a tent, and by careful nursing and treatment he escaped with the loss of the tips of his fingers. During his illness he sent his second in command, Captain Umberto Cagni, on a sledge raid to the Pole. Cagni went on till nothing remained to eat except dog food, and on the way back the dogs themselves were eaten. He attained 86 degrees 33 minutes North, and this remained the record for arctic exploration until Peary won right through to the Pole. Cagni was absent 104 days in the summer of 1899; his return journey was one of great peril and hardship. The plain of ice across which he had gone disappeared, leaving a sea full of floating islands of ice. The exploring party rigged up sails on these islands, but, being unable to steer them, they had to leave hurriedly a piece of ice that began to drift in the wrong direction, and jump to another that seemed to be going the way they wanted. By this extraordinary means of navigation, the ship was reached; and as it had been repaired by the carpenters, the duke and his men were able to get safely back to Italy.

An unhappy love affair with the beautiful daughter of a United States senator drove the young duke forth in search of further adventures.

In search of excitement, he turned to the Mountains of the Moon, on the borders of Uganda and the Congo Free State. Here, beneath the scorching heat of the Equator, rose the snow-crowned heights of the Ruwenzori (16,690 feet), discovered by Stanley in 1887, but still unscaled by man. Some men of science, sent out by the natural history branch from the British Museum, were attempting to conquer the virgin peak of the range when the Duke of the Abruzzi arrived on the scene. A bold plan of attack that he had drawn after his study was so well prepared that

he carried off the honor of the climb under the nose of the Englishmen (1906). During the summer he or members of his party climbed all the highest peaks and determined the main lines of the watershed. In 1909, he ascended Mount Godwin-Austen (28,250 feet), in the Karakoram Mountains in Asia. In 1911 the duke was commander of the *Vettor Pisani* at the head of a squadron in the Ionian Sea to protect Italian commerce from Turkish torpedo boats. His brilliant work on the Albanian coast aroused the alarm of Austria and he was ordered to suspend operations. The duke was in temporary exile for a time, but when the occupation of the Ægean Isles was decided upon he reappeared at the head of the navy and occupied them without difficulty. He tried in vain to force the Dardanelles — the last naval operation of the war.

In 1914 he was made Commander in Chief of the Italian Navy and served as such throughout the Great War.

ROALD AMUNDSEN

Discoverer of the South Pole

CAPTAIN ROALD AMUNDSEN, the discoverer of the Northwest Passage and of the geographical South Pole, is the son of a Norwegian shipowner. Born on July 16, 1872, at Borge, Smaalene on Christiania Fiord, he comes of a family of sailors. Against his wishes, he was sent to study medicine in Christiania University. It was in the days when the first achievements of Nansen had begun to stir the slumbering imagination of the descendants of the ancient vikings. The lads of Norway fell to dreaming of the deeds of Eric the Red, who sailed from Norway to Iceland, from Iceland to Greenland, from Greenland to America, in the wild old pagan times when other vikings were harrying England and Ireland, and conquering Normandy. It was a renaissance of the spirit of adventure, and Amundsen's career was changed by it. Like many other Norwegians, he resolved to become an explorer, and, throwing up his post, he went as a deck hand on a sealing ship to gain experience of arctic navigation.

He was already an eager student of the scientific problems of the icy wastes of the North. And when he returned from his first voyages in pursuit of seals and whales and practical experience, he put himself under the tuition of Dr. Georg von Neumayer (1826-1909), the great German authority on magnetism. After devoting a long period to this kind of study, Amundsen went as first officer of the *Belgica* to the antarctic regions — still in search of scientific and practical knowledge. The little ship crossed the Antarctic Circle on February 15, 1898, and was caught by the ice-floe, and held prisoner for a year. So her mate was among the first of men to experience the long darkness of the antarctic night. There was little light on the ship, and the expedition suffered greatly from inadequate food.

On returning to Norway, Amundsen spent some time in navigating the icy seas of the North, and by 1902 he had learned all there was to know about the most difficult and perilous kind of seamanship. So the next year he began his own great work of extending the boundaries of human knowledge and power by setting out to find the Northwest Passage, marked by the graves of Franklin and other brave but baffled explorers. He combined the methods of the ancient vikings with the machinery of the twentieth century. Instead of taking a large crew in a great ship loaded with provisions, he went with six men in a tiny sealing craft, the *Gjoa*, of 46 tons. The old, strong sealing-boat was, however, fitted with a petroleum motor of 39 horse-power. She left Christiania on June 17, 1903, and crossed the Atlantic, sailing between Greenland and Baffin Land. On August 24, the little vessel entered Peel Sound, making slow progress through the ice along the foggy coast of Boothia, where Franklin died.

Here Amundsen and his men had a very narrow escape from the same terrible death from starvation that befell the English searchers after the Northwest Passage. While the *Gjoa* was anchored by a small island, the men on shore saw a pillar of flame shoot up from the engine-room of the ship. There were seven thousand gallons

of petroleum on board, besides large quantities of gunpowder. It looked as if the vessel were doomed, and the loss of the vessel meant the loss of lives. Fortunately, the engineer had not left his post, and as he battled with the fire the men ashore hurried to his aid, and the flames were got under control. Some cotton had become saturated with petroleum, and had ignited through contact with the engine.

Soon after this exciting adventure, Amundsen set up his winter quarters some distance below the magnetic Pole, and spent two winters making a scientific study of this center of interest to all navigators. For nineteen months he conducted continuous magnetic observations, which were kept up night and day without interruption. He found that the magnetic Pole, that had first been located by Ross, was not a fixed point on the earth, but a shifting center of mysterious force. The results of his lengthy and delicate studies were of very high importance in science, even though he did not discover the geographic Pole itself.

At the northern focus of terrestrial magnetism, Amundsen met and became very friendly with some unknown tribes of Eskimos, one being strangely of the Indian type. From them he learned much.

All this time, the Northwest Passage was open to Amundsen, but with praiseworthy restraint he put off accomplishing it until his magnetic studies were completed. He owed his success in finding the sea channel to the excellence of his knowledge of magnetism, and to the exquisite magnetic instruments he had brought with him. For when he arrived at a point where all students of polar exploration said, "Go north, and find the open sea," he looked at his instruments and found that they indicated "Go south." Had he gone north, he would have failed like other men, but by turning south he found an open way along the extreme edge of Canada. On August 30, 1906, he entered Behring Strait; then the next day he called at the gold-digging town of Nome, in Alaska, and met with an enthusiastic reception. So the first voyage through the Northwest Passage came to a happy end.

Amundsen's next aim was to win to the geographical North Pole, and he fitted out Nansen's old ship, the *Fram*, for this purpose. But, hearing of Peary's achievement, he turned south, and raced against the ill-fated Captain Scott for the honor of attaining the geographical South Pole. Taking the *Fram* to the great ice-barrier, he reached the Bay of Whales, charted by Ross in 1841. The work of laying depots for the march to the Pole was completed in April, 1911, and so well was everything planned by the experienced explorer that the affair was a pleasant excursion. There was no suffering from hunger and exhaustion, and the health of the men and sledge-dogs remained good. There was not even need for the party to go on fixed rations. The weather was very favorable, and on October 20 the start was made. On November 17 the junction of the ice-barrier and the land was reached, and Amundsen and his men began to climb the great polar tableland. The greatest height, 10,750 feet, was reached on December 6, and soon afterwards the land began to slope down towards the Pole. On December 16, 1911, the expedition camped on the South Pole. Observations were taken hourly by four men for twenty-four hours, and the plateau was given the name of King Haakon VII.

Captain Amundsen has now started on a seven years' journey to the North Pole and hopes to complete the last portion of the trip drifting ice-bound in the *Maud*, especially constructed to withstand the enormous pressure. He has an airplane on board to extend his area of observation.

WILLIAM BAFFIN

Greatest Polar Seaman of Elizabethan Times

WILLIAM BAFFIN, the great polar explorer of the time of Shakespeare, was a Londoner of humble birth. He was born somewhere about 1584. Baffin got so near to the Pole that for hundreds of years no one followed him, and no one believed in his discoveries. He made excellent maps of the icy seas through which he sailed, but geographers would not believe in his voyages, or make use of the information he obtained.

He seems to have been born of poor seafaring folk on the riverside of London; he was uneducated, but by self-teaching he became a graceful writer, a mathematician and the most scientific navigator in Europe. Even Barentz cannot compare with him in science, but, unhappily, we do not know how he won his extraordinary knowledge and developed his talent for inventing devices to do what no other man could do. Our knowledge of terrestrial magnetism in the sixteenth century depends entirely upon his observations made in the neighborhood of the magnetic North Pole. By studying the sun and moon and stars in the high polar regions he fixed his positions with such accuracy that explorers in the nineteenth century were able to follow him easily. He emerges into the light of history in 1612, when he sailed as pilot under Captain Hall, of Hull, on a voyage of discovery to Greenland. While examining the west coast of this great polar island the Englishmen were attacked by Eskimos; Hall was killed, and the expedition returned home.

Baffin then entered the service of the Muscovy Company, an enterprising body of London merchants, at the head of whom was Sir Thomas Smith. Smith was the soul of most of the English polar expeditions of his age; he fitted out ship after ship for the discovery of a polar passage to China. Baffin served as pilot on two voyages to Spitzbergen, in 1613 and 1614. Then he was appointed pilot of a little ship, the *Discovery*, of 55 tons, with a crew of sixteen men. He set sail from Gravesend on March 18, 1615, on an attempt to find the Northwest Passage by the north of Canada, but he was stopped by ice at the end of Hudson Strait, and only reached the western end of Southampton Island. But Smith was not daunted by this failure. The next year the *Discovery* was again fitted out, and, on March 26, 1616, Baffin set out on his last and most important arctic voyage. On rounding Newfoundland he kept straight to the north, avoiding Hudson's route. Passing down the strait that Davis had discovered in 1587, he got clear of the ice and sailed into the vast Baffin Bay.

In this unexplored region Baffin saw thousands of whales and seals and walrus. The whales especially were so little frightened that he was able to sail his ship close up to them. On some islands he met Eskimos, who brought him a great quantity of horns, possibly obtained from the musk oxen wandering amid the snow of northern Canada. At the extreme north of the bay he discovered a sound leading to the North Pole, which he called Smith's Sound, in honor of Sir Thomas. It was through this sound that Peary traveled in 1909, and reached the North Pole. Baffin was not greatly interested in it, because it led past the northern coast of Greenland back into the North Atlantic Ocean. What Baffin wanted was a westerly passage to China. He found it at the place he named Lancaster Sound, but the sea began to freeze and the crew became ill with scurvy, so he was forced, at the peril of being caught by the ice and starved to death, to return to England.

He found no one there ready to supply the money for another expedition. But he was not a man to be daunted by want of money. He resolved to sail to China, as a working pilot, and strive for an opportunity of attacking the problem from the northern coast of China. Helped, no doubt, by Sir Thomas Smith, he obtained the command of the *London*, one of the ships of the East India fleet. She set sail from Gravesend on March 25, 1620, and, with the rest of the fleet, sailed south to the Cape of Good Hope, and then turned northward by Madagascar. Here news was received that a combined force of Portuguese and Dutch ships was waiting at the entrance of the Persian Gulf to cut off and attack the English vessels. But the Englishmen did not wait to be attacked; they went in search of the enemy, and found them. The English admiral stayed with Baffin on the *London*, and was killed by a great shot, but before he died had put the Dutchmen and Portuguese to flight.

The Portuguese had built a strong fort at Ormuz, from which they dominated the country and oppressed the people. The Shah of Persia implored the Englishmen

to help him against the Portuguese; so the four English ships anchored off Ormuz, landed their guns, and threw up batteries. On January 23, 1622, Baffin went on shore with his mathematical instruments to take the height and distance of the castle wall, and so find the range for his guns. But as he was making his observations a shot from the castle struck and killed him.

VASCO NUÑEZ DE BALBOA

The Man Who First Traveled across America

VASCO NUÑEZ DE BALBOA, the first man to cross America, was born in 1475. He belonged to a poverty-stricken noble family of Xeres-de-los-Caballeros, in Spain. Fame was won by him in a series of flights from his creditors. He feared a dun more than he feared death. So when Bastidas, a rich man of Cadiz, resolved to grow richer by winning gold in the New World recently discovered by Columbus, Balboa was glad to go with him in search of El Dorado. But Bastidas was unfortunate. He landed at the island of San Domingo, where the governor, already notorious for his infamous conduct to Columbus, arrested the merchant on a false charge, and sent him back to Spain.

Balboa, however, managed to settle in Hayti, and obtain a grant of land and a gang of Indians to work it. But the Spanish adventurer was so unused to handling any sort of wealth that his estate was soon loaded with more debts than it was worth. His creditors began to pester him, and he was anxious to escape from them. An expedition was starting to found a colony on the mainland at Darien, and Balboa, being in very sad circumstances, was naturally eager to join it. Unhappily, there was a law that no insolvent debtor was to board a ship bound for the mainland. But the duns pressed, and the great Spaniard who was to win fame

"when with eagle eyes
He stared at the Pacific — and all his men
Looked at each other with a wild surmise —
Silent, upon a peak in Darien,"

was equal to the occasion. He ordered a big cask to be rolled on to the ship in which the leader of the expedition sailed. Balboa was in the cask!

On arriving at the mainland, the Spaniards found the natives more warlike than the Indians of the islands, and they were unable to make a conquest. Defeat was followed by dissensions, and the baffled adventurers took refuge at Santa María la Antigua, upon the Gulf of Darien, and elected Balboa to command the colony — the first on the mainland of America. He had won their admiration by his bravery.

He proved to be a good governor; he was just in his treatment of the natives, and he allowed no unnecessary cruelty. By mixing with the Indians he gradually learned of the existence of a land of gold. Six suns away — six days' journey — he was told, there was another sea that washed the shores of Peru, a land that was very rich in gold. Accordingly, in 1513, he determined to set out in quest of the strange western sea. He assembled a troop of a hundred and ninety volunteer soldiers, and led them over the mountains and through the tropical jungles of the isthmus of Darien. Some warlike tribes tried to bar his way, but he broke through them. After twenty-five days of march-

ing and fighting, the expedition reached a mountain top, from which they descried the vast expanse of the Pacific Ocean. Four days later, Balboa, his drawn sword in one hand and the banner of Castile in the other, advanced to the shore and took possession of the land of Panama upon the Pacific coast. Balboa crossed the isthmus several times, and always in some new direction.

Unfortunately for Balboa, and perhaps for the Peruvians too, a new governor was appointed over Darien through intrigues at the Spanish Court. He proved a cruel and obstinate man. Balboa endeavored to make friends with him by marrying his daughter, and the famous explorer was then allowed to go on with his land explorations. But when he began to build ships, and to prepare an armament for the conquest of Peru, the new governor, out of jealousy of the probable success of his subordinate, brought a false charge against him, in 1517, and had him beheaded. The murder retarded the conquest of Peru for twenty-five years, which was something gained for the empire of the Incas.



VASCO NUÑEZ DE BALBOA AT THE COURT OF A NATIVE PRINCE

THE ETERNAL MILLS OF GOD

The Mighty Energy that Drives the World-Machine,
and the Fear that the World will Run Down

THE UNIVERSE, SO OLD AND YET SO YOUNG

THE universe is often looked upon as a machine, a great piece of construction which was made in order to "go," and goes accordingly. There is no doubt, indeed, that the universe is a machine, though it is also immeasurably more; and evidently the machine goes, for we see its motion and action on every hand. Indeed, they are displayed in the hand that writes these words, and the rotation of the eyeballs which scan them.

The machine has therefore some kind of power or motive force within it; and we are naturally impelled to ask whether this power was put into it, in the beginning, and whether it is now, however slowly, in process of running down. Science cannot give the ultimate answer to our question, but it is from science that we must secure the data upon which to base our speculations and conclusions. The idea of the universe as a machine whose power will finally be exhausted corresponds to one of the oldest and commonest notions in the world; and we shall find that it took scientific form, in the nineteenth century, as the doctrine of the "dissipation of energy," which was introduced by Lord Kelvin, and which only since his death began to find opponents. Lord Kelvin thought that the universe must run down and come to a dead level of heat and power, so that neither motion nor activity nor change could be found in it again. It would be a dead universe, which had run its allotted span of life, and was now no more than a changeless corpse.

This view of things involves an end to the universe as an active world when its power has given out; and a beginning

when its power was put into it. Opposed to this view are a number of philosophers and scientists who hold that the universe, though it is a machine and needs power to run it, is nevertheless a perpetual motion machine, whose power to go is inseparably bound up with it so that it can never run down like other machines. In order to form any reliable judgment in this matter, or even to be able to grasp the questions at issue, we must try to get as clear and as complete a knowledge as possible of the character of the motions and forces involved in the processes of nature; and the fairly modern idea of "energy" must be our guide.

In this matter we all certainly owe a great debt to the scientific work of the late Lord Kelvin, whether with a small minority of scientists we reject, or with the great majority of them we accept, the theory of the dissipation of energy, a theory he so carefully elaborated and so cogently presented that no scientist was found in his day to doubt its validity.

The first universal fact about energy is its incessant transformation. The whole of the activities of the universe, its changes of form and motion, the production of light by a star or a candle or a glow-worm, or an electric current in a wire—all these depend upon the transformation of energy. All forms of energy are forms of one and the same thing, and they can be transformed into one another—light into heat, heat into motion, motion into light, chemical energy into motion, as when a bullet is fired—and so forth. In this process the form of the energy is changed, but its substance remains.

THIS GROUP EMBRACES THE SCIENCE OF ASTRONOMY, BOTH OLD AND NEW

On inquiry, we find not only that it is really one thing which is capable of so many transformations, but also that it remains constant in quantity, however much it be changed. The householder expects so much electric light to be derived from so many units of electrical energy; and if his lamps have been burning for a certain number of hours each month, he expects the bill to be for the same amount.

How the motor turns the energy of a gallon of gasoline into 20 miles of motion

So much electrical energy yields so much light energy. It is true that the energy the householder pays for is partly turned into heat, which he does not want, and partly into light, which he does want; and that he gets thus different results with different types of lamps. But the law of the equivalence of energy is observed nevertheless; and the only difference is that the more economical lamp turns a higher percentage of the electrical energy into light energy, and a smaller percentage into heat energy.

Again, the motorist gets his pleasure by turning the chemical energy of gasoline into the energy of motion of his automobile. Though he may know nothing of the law of the conservation of energy, which we are about to consider, he does at least know that if his gasoline has run out his car will not run on. No gasoline, no motion. And he also knows something of the law of the equivalence of energy, for he reckons that one gallon of gasoline is equivalent to, say, twenty miles of motion, or ten miles of motion if the car's weight be doubled. If this equivalence be not observed, he knows that something is wrong, and examines the engine, adjusts the bearings of the wheels or re-inflates his tires. In so doing he is a man of science, recognizing and assuming the truth of the law of the equivalence of energy.

Every act and fact of the world's doings is an illustration of this universal law; and we should look round for ourselves until we realize how universal it is. Particularly must we observe that this transformation and equivalence of energy is true in any direction.

The potential energy waiting to spring and the kinetic energy that we can see

Heat, as in a steam engine, will produce motion, but we have but to rub our hands on a carpet to realize that motion can be turned into heat; or to look at the shooting stars that flash through the atmosphere, and consider that these are dark bodies, flying through space, which suddenly encounter the resistance of our air, and lose much of their motion, which is transformed into the heat and light that we see them by.

In all these transformations we can recognize two great types of energy, which are to be observed — as all these laws may be observed — equally in the stars or in the behavior of our own bodies, or in the growth of a seed. Energy may either be latent, waiting to spring, coiled up, but not let go, in which case we call it "potential energy"; or it may be actual, active, visible, moving, in which case we call it "energy of motion," or "kinetic energy," from the Greek word for motion.

Having got so far, men made a great discovery which alone was wanting for a greater discovery still. They proved that heat is a mode of motion, or kinetic energy; and that a given amount of heat is always equal to a given amount of work — that is to say, such work as lifting a given weight to a given height. So much heat will do so much lifting, and the energy produced by the lifting will reproduce just the same quantity of heat.

The potential energy of a twenty-dollar bill that turns into very rapid motion

Heat, therefore, which is almost always produced whenever energy is transformed — whether we want it or not — is a form of energy, and we cannot omit to reckon it in when we try to understand the laws of energy. The heat produced by an electric bulb or a candle may be a nuisance if we only want light; and the motorist is not at all pleased at the fact that much of the energy which he has paid for in his gasoline turns not into the motion he wants, but into the heat which he doesn't want, and which, indeed, often hampers his engine, so that he loses his motion.

WORLD'S RECORD HIGH VOLTAGE ARC

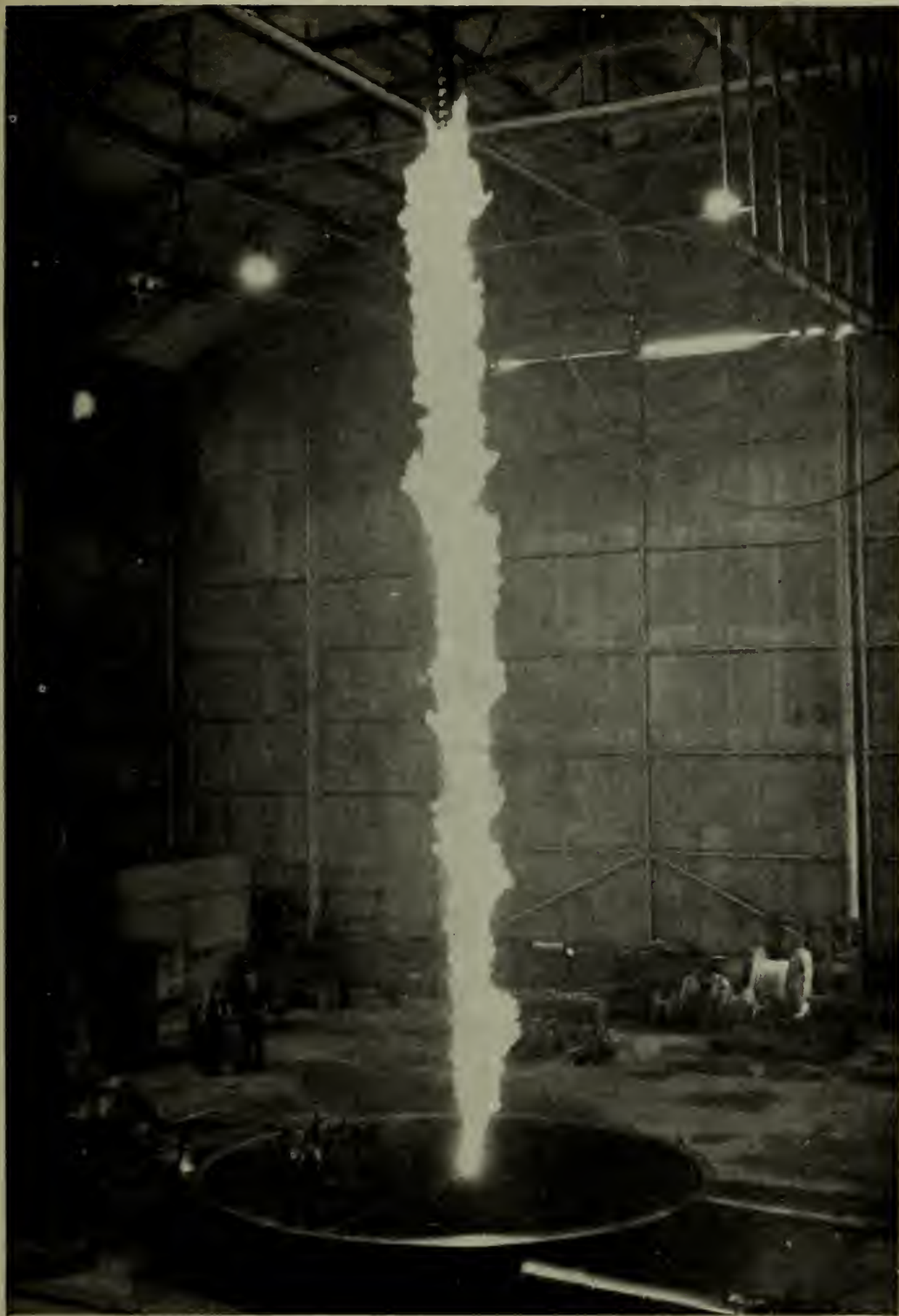


Photo International Newsreel

ARC 55 FEET LONG PRODUCED BY THE HIGHEST VOLTAGE TRANSFORMER IN THE WORLD — A MILLION VOLTS IN A SINGLE UNIT

The man of science, however, is well pleased to study the production of heat in these cases, and to realize that the electricity, or the wax, or the gasoline, means a store of energy which may be turned into light, or motion, or heat, or any combination of these; and that in each and every case the law of equivalence is observed. Just so is it observed when a piece of paper, a check or banknote — which has only potential energy, so to speak — is turned into the energy of motion — only too

terms may be a little unfamiliar, but the facts are really simple and reasonable; and we are perfectly familiar with the principle of them in our daily lives whenever we buy anything and wait for the change, or in any process of exchange whatever.

And now we come to the great discovery. Suppose we break our banknote and then decide to turn the change back into a note again, and find that the change is ten cents over or short. We know that something



ELECTRICAL ENERGY IN THE SKIES—PHOTOGRAPH OF A FLASH OF LIGHTNING

All forms of energy are forms of one and the same thing, and can be transformed into one another—light into heat, heat into motion, motion into light. This photograph shows electrical energy in the universe manifesting itself in the familiar form of lightning; some of it turns into sound, but thunder cannot be photographed.

rapid!—of, say, four pieces of gold, or eighty pieces of silver, or two thousand of “copper,” or any combination of these, *provided that* they are equivalent to twenty dollars. Just so, also, the gold and silver and copper, or stamps or what not, may be gathered together again, and transformed into the potential energy of another check equivalent to that for which they were drawn.

So much for the doctrines of the transformation and equivalence of energy. The

is wrong. We never believe that a dime disappeared by annihilation, nor that a dime doubled itself spontaneously. Either a dime has slipped through a hole in our pocket, or a dime was in the pocket to begin with. Some such explanation there must be. We decline to believe either that a dime became nothing or that nothing became a dime.

If we agree so far, we are indeed prepared to agree with the law of the conservation of energy, which simply asserts about

all energy, in all times and places, and through any kind and number of transformations, what we believe about the form of energy called money, in such a case as we have supposed. The law is not completely described by its name, which, indeed, applies to only half of it. The energy which makes and molds and moves the universe is indestructible; its quantity is never decreased. Nor can any more of it be made; its quantity is never

kinds, and the term is indeed a bad one. But some are absolute generalizations, which either apply everywhere and always, or are untrue and apply not at all. The law of the conservation of energy is one of these. If anyone anywhere by any combination or application of the forces of nature makes something out of nothing, or gets power without having spent power, which is indeed to *create* in the full sense of the word; or if anyone can by any



ELECTRICAL ENERGY ON THE EARTH—AN ELECTRIC SPARK MADE BY MAN

The picture facing this is a natural electric spark, which we call "lightning"—a flash of natural electricity set aglow in the heavens. The picture on this page shows a flash of man-made lightning, being a photograph of an electric spark, such as occurs in a motor. Both these photographs show manifestations of the same form of energy.

increased. That is the law of the conservation of energy, and its importance cannot be too highly rated.

Before we really set ourselves to consider what it means, let us meet the supposed exception furnished within the last few years by the discovery of the unheard-of behavior of radium. We must clearly realize that this is one of those scientific laws of which the whole essence is that there can be no exceptions to it. What are called "laws" in science are of many

natural process destroy power so that it is really made into nothing, annihilated, then the law of the conservation of energy is untrue, and there remains no fixed foundation on which to build a real science of nature's operations.

We commonly expect, as this law assures us must be the case, that we cannot get heat and light without using up energy of some kind—chemical energy, electrical energy, or what not. Radium, however, displays a form of action called "radio-

activity," which involves the production of heat and light, among other things; and it seemed at first that it would do so for any length of time, without any energy being supplied to it from external sources.



A POWER WHICH RESISTS GRAVITATION

Under the influence of radiation-pressure acting upon it, a comet's tail turns away from the sun. While the relatively dense head of the comet is drawn towards the sun, the radiation-pressure on the tail, which is extremely tenuous, is stronger than the gravitational pull of the sun; and the tail of a comet, shown in this photograph, is one of the very few things in the universe of which this is true.

Unwise commentators therefore declared that this great law, the establishment of which was one of the most magnificent achievements of the nineteenth century, had been broken and falsified by the first

discovery of the twentieth. No one of really scientific and impartial mind could believe such nonsense. The power of radium must come from somewhere, or else a miracle is before us, and miracles, as we have said, cannot be a rule of action in the universe. Our business in such a case is to jump to no conclusions, least of all to a conclusion which contradicts all our experience of nature's mode of acting, but to suspend judgment and to examine more carefully the facts before us. That examination, as we already know, revealed that radium derives its energy from a mighty reservoir within its atoms; and, indeed, if the law of the conservation of energy had been in need of further confirmation, the recent work on radium would have supplied it abundantly.

One other point before we discuss the full meaning of the law of the conservation of energy. It is a point which helps us to understand the meaning of the law perhaps better than anything else can. We have tentatively called the universe a "perpetual motion machine." Certainly there is no other perpetual motion machine, in the ordinary sense of that phrase, and now we can realize why all the would-be inventors of such machines have failed.

They have tried to get something for nothing; cunningly to score off nature, and cheat her into giving them twenty dollars and ten cents for a twenty-dollar bill — or for nothing at all. They have tried to make a machine which would work without requiring power. Since work cannot be done except with power, this means that they have expected their machines to create power out of nothing. Many scores of years have passed since the Paris Academy of Sciences decided that it would no longer even look at inventors' specifications for such machines.

That decision was taken long before the law of the conservation of energy was established and proved. Those who had thought clearly and sanely about the subject knew, from the very nature of finite things, that these inventors and all future inventors of such machines must be deluded. We have only to grasp the real nature of the problem these inventors set

THE MOST TERRIBLE EXAMPLE OF CHEMICAL ENERGY THAT CAN BE SEEN IN THE WORLD



The first universal fact about energy is its incessant transformation, upon which the whole of the activities of the universe depend. All forms of energy — light, heat, motion — are different forms of the same thing. The firing of a big gun, shown in this photograph, is the most remarkable example that science has yet made possible of the transformation of chemical energy into motion, brought about by the sudden changing of gunpowder into an enormous volume of pent-up gases.

themselves, the problem of absolute creation out of nothing, to know that they cannot succeed. For to create even the least thing requires infinite activity and hence is utterly beyond the power of any man or of any instrument fashioned by his finite hands.

Creation and destruction by finite agents impossible

This brings us to the heart of the matter. Both creation and destruction by any finite agents are denied by this law. We simply misstate and misunderstand it if we do not realize that it contains both these denials, and that they are the two halves of one truth. The "perpetual motion" inventor fancies he can create power out of nothing; and he fails invariably. Many other people suppose that power can disappear, not merely in the sense of being no longer visible, but in the sense of being made into nothing; and their mistake is really the complementary one to that of the would-be inventor.

We are to accept it as proved by all the evidence, and as a necessary consequence of the nature of finite beings, that all the universe, devoting itself with all its powers to the making of just one more iota of power — just so much as would stir the least grain of dust — would fail; and also that if all the universe, except one iota of power, were to set upon that and seek to destroy it, the attempt would fail. That is what the conservation of energy means.

The power that slips from our grasp and goes out into the universe

And further, whenever power seems to disappear, with nothing to show for it, we must be absolutely certain, appearances notwithstanding, that that power has gone somewhere. It may be lost to us, and too often, indeed, that is what has happened, but it is not lost to the universe. Our motor-engine may simply make itself hot, and refuse to go. We have lost the power, and cannot recover it, for the heat glides away into the air irrecoverably; but it is there, nevertheless, and the universe may have means of making it available again in its own good time.

This illustration leads us to reconsider the doctrine advanced by Lord Kelvin, called by him "the dissipation of energy." Kelvin had set himself to study the tendencies of energy in the course of its transformations, and he found that it always tends to escape from usefulness.

The heat that runs to waste in all the workshops of man

It tends to spend itself in the form of heat, which scatters its force on all sides, and can no longer be employed for purposes of work. This waste is the incessant problem of the engineer, and of those who provide for artificial lighting, or deal in any of the numerous forms of the transformation of energy.

The tendency of heat is to spread itself out, like water, until it finds its own level, where all things are at the same temperature. If the motorist could catch all the heat into which even the best engine must necessarily transform a fraction of the energy in his gasoline, then there would be no waste. But he cannot. The heat escapes him, and is lost. If we do not grasp the great distinction between the annihilation of heat or any other form of energy, and its loss or waste, we need only compare it to the case of money turning into nothing in our pockets, or dribbling away through a hole. The first cannot and does not happen; the second may and does.

Now, said Lord Kelvin, this process of the gradual leakage, waste, and loss of the available energy of the universe is always going on. So long as one thing is hotter than another, power is available, and work can be done, as is the case of the sun, which is hotter than the earth, and provides power for the earth. But in this very act, and in all other transformations of energy, the heat levels of the universe, so to speak, tend to become the same; and when that happens they can no more be made to do anything than the water which has fallen into the pond below can drive the mill-wheel above it. All energy runs to heat, and all heat runs to one level; and the question then is what is to drive the mills of the universe?

The hopeless theory of a world that must one day utterly perish

This is the doctrine of the dissipation of energy. It depicts the sun and stars, the comets and nebulae, gradually becoming exhausted, sinking to a uniform dead level of temperature, where they are not unheated, but where their heat is useless — as the “mill-wheel cannot turn with the water that is past.” It depicts the motion of suns and planets and all other things gradually lost, because of friction, which, as we have lately observed, tends to turn motion into heat. And since the motion of the heavenly bodies, which keep them in their orbits, must die down, they will all fall together, by the law of gravitation, until the matter of the universe, all the stars, bright and dark, and planets, and everything else, will be gathered together into one immense but impotent heap, not devoid of heat, but all of the same temperature, and therefore inactive. In a word, the clock or machine will have run down; and will have proved itself to be just like man-made machines after all, and not a perpetual motion machine, as we had hoped the universe would prove to be.

Such is the law of the “dissipation of energy,” which is still accepted by the majority of men of science, and was regarded, until very recently, as one of the definite and established results of scientific inquiry. If it be true, it necessarily involves a beginning and an end; and forces us to accept the conclusion that this end is inevitable, a universal death without hope of resurrection — unless the Author of the universe wills to renew its vigor and to establish new heavens and a new earth. Can science tell us aught of this renewal which those who believe in God confidently expect? Both philosophers and scientists join in their efforts to find in the nature of things evidence that will obviate the necessity of admitting the forebodings of a dead and useless universe. They point to the skies where new suns and worlds seem ever to be forming, with no signs of old age; or rather, they say, though “suns grow cold, and the stars are old,” other suns grow warm and other stars are born.

Theories in opposition to the conclusion that the universe will run down

Some base their theories of the perpetual youth of the universe on analogies and on general principles of universal efficiency in nature: thus Herbert Spencer argued that there *must* be compensating forces at work which would build up and make new beginnings no less real and active than those which seem to be running down. We all know, notwithstanding the decay of autumn and the “dead of winter,” that life is not dead, but is active under the soil, and that spring will return. In some such way, they say, there surely are forces at work in the universe, even though they be too deep for our eyes, which have promise of rejuvenescence in them, forces through which “the most ancient heavens are fresh and strong.” Others, again, admitting the truth of the theory of the dissipation of energy, take refuge in the supposition that the material universe is actually infinite in extent; all the stars, they say, which are visible to us either individually or collectively, as in the Milky Way, constitute what is called a “galaxy”; why cannot we suppose that our galaxy is only one of very many galaxies so far removed from each other and from us that they are invisible to us; and then what prevents us from supposing that this system of millions of galaxies, each having millions upon millions of stars in them, belongs to a still higher system and so on without end? Under such a supposition or series of suppositions, when the useful energy of the solar system is exhausted, there are countless other stars in our galaxy with which the sun may collide and thus renew its supply; and when countless collisions and renewals and dissipations of energy have made our galaxy run down to stagnation, there are all the other galaxies with which it can collide and thus start the processes of activity again; and so on forever.

This theory is, however, entirely unsatisfactory, first, because its postulates are admittedly without any observational foundation; secondly, because it simply puts off indefinitely the final consummation, with-

out introducing any real principle of rejuvenescence to offset the ever present principle of the dissipation of energy; and lastly, because it postulates an actually infinite number of individual worlds, a postulate that does not recommend itself to sound reason. But whatever be the value or the ultimate outcome of these speculations, which we will not try to carry any further here, recent advances in scientific knowledge have opened our eyes in a marvelous way to new sources of energy the very existence of which had utterly escaped the previous attention of scientists. These new discoveries, while they do not prove that the energy of the universe is exhaustless, nevertheless render it imperative for us to revise the calculations formerly made by mathematical physicists as to the probable duration of the universe in the past and the probable length of time that would be required for the entire dissipation of its total supply of energy.

A great fact that was ignored in the old pictures of the universe

Mathematics is indeed a noble science, but its conclusions, when applied to questions such as these, depend upon the completeness of the evidence it discusses. Continually the confident assertions of mathematicians are falsified in consequence of this dependence — as, for instance, Lord Kelvin's assertion that there was nothing to be expected of toys like flying-machines.

In the great case under discussion there need be quoted only two universal factors, one of which was unproved until about a score of years ago, while the other was never dreamed of. Though universal gravitation always tends to draw things together, there is a form of energy, called "radiation-pressure," which tends to drive them apart. In certain conditions, this force is greater than that of gravitation, so that by it bodies would be scattered, though gravitation was all the while tending to bring them together. Here, evidently, is a fact which was ignored in last century's pictures of the fate which awaits the universe.

How the dissipated heat may possibly play its part elsewhere

Again, radio-activity was unimagined until a few years ago. The forces within atoms, far greater than all the forces outside them, were unknown. The history of atoms, their breaking down, which has actually been proved by observation, and their building up, which is surmised, along with the consequences of these processes, were not only unthought of, but the suggestion of such possibilities would have been scouted as ignorant and absurd. But no one who has ever glanced at this subject, and the possibilities which it opens up, could permit himself to view the theory of the dissipation of energy in quite the same light as he might have done a generation ago. May it not yet be shown that the dissipated heat which results from so much of the transformation of energy, and is lost to our use, and appears henceforth unavailable, may play its part in the up-building of atoms? If so, it would, in due course, become available again, as in the atoms of radium and many other elements. This is only one of the possibilities that present themselves to our minds in this remarkable and unprecedented era of scientific revelations; and the future will pronounce upon them.

Each new discovery magnifies the wisdom and power of the Creator

What that pronouncement is to be we will not venture to predict. But this at least we may confidently assert on the strength of the evidence before us: nature, with its laws, so just and balanced, so varied and yet so unified, shows forth the wisdom and the power of its Cause and Author, and proves that wisdom and power to far transcend our own. Each new discovery makes us realize this truth; for just where we thought nature to be imperfect and to need correction, a fuller knowledge makes us see the error of our judgment and lets us understand that the world is fashioned as it should be, the imperfections being rather the result of our meddling or our ignorance. We have still much to learn.



AN ARTIST'S CONCEPTION OF A 50-MILE VERTICAL

Age of Man	Drift
Age of Mammals and Birds	Tertiary Sands and Clays
	Cretaceous Chalk
	Gault Clay
	Oolitic Limestone
Age of Reptiles	Lias Clay
	Trias Sandstones
	Permian Limestone
Age of Land Plants	Carboniferous Coal
	Carboniferous Limestone
	Devonian Old Red Sandstone
Age of Fishes	Devonian Limestones
	Silurian Limestones
Age of Crustaceans, or Shelled Animals	Shales and Sandstones
	Cambrian Limestones
Age of Molluscs and Trilobites	Cambrian Flagstones
Lowest Forms of Life	14 miles deep . .
Igneous Rocks and Modifications with no Traces of Life	Gneiss
	Schists
	Granites
	Basalts
	Porphyries and Trachytes
	50 miles

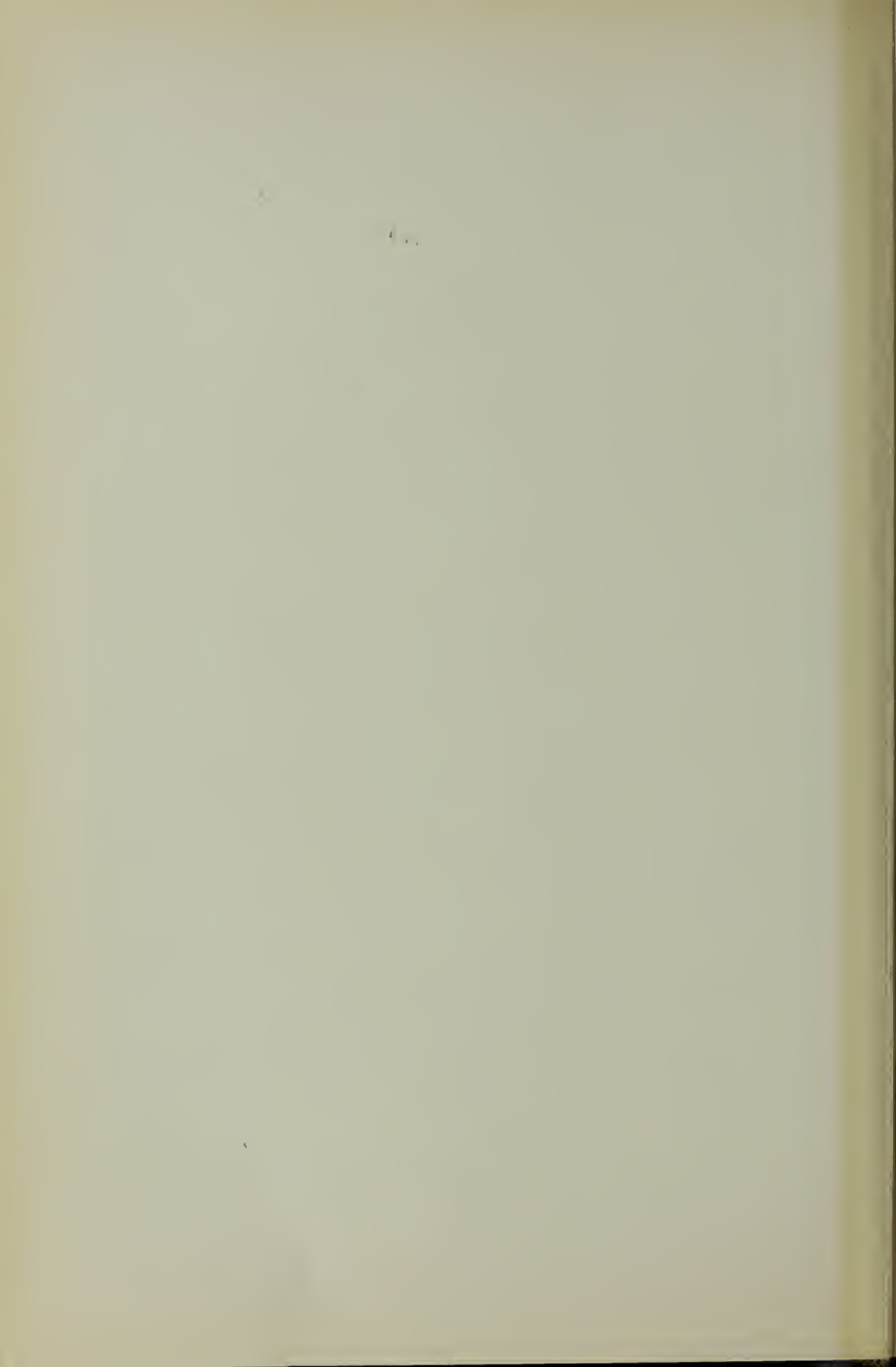


By the earth's crust (a term left over from the times when the earth's interior was supposed to be a molten mass) over 6 miles in height, the deepest scratches on the earth's face are parts of the Grand Canyon, about 6000 feet deep. The folded and tilted strata that form its greater part. These strata are the leaves in the earth's biological life forms. Our artist, without any pretense of drawing to scale, hints at the succession of different strata as they occur, for our earthquakes, mere tremors or violent shocks like the Japanese disaster of September 1, 1923, to a depth the water would be in the vapor state. The igneous rocks, direct and metamorphosed, underlie these sedimentary rocks, a sequence of rocks, sedimentary, igneous and metamorphic.

CAL SECTION THROUGH THE EARTH'S CRUST



en mass) we mean that very thin outer shell of which we have some direct knowledge. No mountain is feet, our lowest boring is a little over 7000 feet, so most of our knowledge of this crust is derived from hy; in them we read the sequence of rock events and the rise, culmination and decline of many extinct a, bent, folded, distorted and broken. The faults, or breaks with displacement, are responsible, when 923. Two water lakes are pictured buried in the strata, though it is very probable that at the indicated edimentary in the picture, and lower down is a pocket of molten rock. The table at the left gives the e, not found however in this order in any one locality.



THE EARTH'S UPS AND DOWNS

The Great Upheaval in which Mountains Rose
from the Sea and Ocean Depths were Formed

SOWING THE DUST OF CONTINENTS TO BE

WE have seen that the earth cooled down till it formed a permanent crust, but it must not for a moment be imagined that the primeval crust has persisted unchanged till modern days. The original crust was hot, still in process of cooling, still wrinkling and puckering, still splintering and spluttering, still grinding and griding, still heaving and subsiding. It was also a dry crust, and a hard crust, and it must have taken ages to brim the ocean beds and emboss the continents. Between the first little steaming puddle and the Pacific Ocean, between the first little lava island and the summit of Mount Everest, must have been many æons and many agonies.

By what stages earth attained its present contour and its present disposition of land and water we can only surmise.

According to one very interesting theory, the earth, as soon as it had tossed away the moon, reassumed a pear shape, and round the neck of the pear gathered the first great sea. The big end of the pear would thus be a great continent, and the small end of the pear would emerge as a small continent in the middle of a great sea — the primeval Pacific Ocean. There would thus be a land hemisphere and an ocean hemisphere. The land hemisphere is supposed to have afterwards collapsed in places, forming the Atlantic, Mediterranean, and Indian Ocean, and there is a good deal of independent evidence to show that these seas were originally dry land.

Even now we find signs of this primitive division into land and sea hemispheres, for it is still possible to divide the globe into two hemispheres, the one containing

almost all the great continental masses — Europe, Africa, North America, most of South America, and most of Asia — and the other containing comparatively little land — Australasia, New Zealand, a bit of South America, and a bit of the Malay Peninsula.

In the earliest geological times it is probable that a shallow sea spread over almost the whole face of the globe, and that the dry land consisted simply of groups of great and small islands. In those days Africa was probably represented by a few scattered islands not much bigger than Madagascar, and India by an island not much bigger than Ceylon, and America by a few islands not much bigger, taken together, than Australia, while only a corner of England was visible. By degrees, however, as the crust contracted, the ocean beds deepened, and the land areas increased, and sea and land established permanent spheres of influence, so to speak.

All great upward changes in the contour of the earth's crust have been due to the crumpling action of contraction. The earth's crust is not homogeneous in composition; and when it cooled it solidified unequally, and when it contracted it contracted unequally. Professor G. A. Daurée illustrated the principle of the contraction of the earth by means of a child's balloon. To the outside of such balloons he applied partial coatings of adhesive paint, laid on in various patterns. He then allowed some of the air to escape, and found that the balloons contracted irregularly. Those portions stiffened by paint contracted less than those unstiff-

ened, and rose like islands traversed by wrinkles above the general surface. In some such way the unequal contraction of the unequally stiffened crust of the earth may have produced the inequalities of its surface, the mountains and ocean beds.

Some of the causes of upheaval in the earth's crust

Even after the present continental and ocean areas were fixed the land must have continued to rise and fall in a see-saw fashion, so that at one time one bit was up and then another bit; and geological evidence shows that almost the whole land surface has been submerged at some time. The cause of the upheavals is mainly the contraction of the earth's crust; the cause of the subsidences is mainly the wearing away of the land by rain and rivers. But we shall return to this subject later on, when we come to speak at greater length of mountains and the way in which they are made.

In early days there were tremendous upheavals of deposits from the bottom of the sea, and these were gradually worn away by the action of rivers and rains, and deposited as mud and debris on the sea-floor again. In the so-called "Proterozoic Age" of the North American continent there were three great sedimentary upheavals from the floor of the sea, and sedimentary accumulations 18,000 feet, 14,000 feet, and 50,000 feet deep were successively raised into mountains. After each upheaval followed æons of wear and tear, and the great mountain ranges were gradually washed away. The Appalachian Mountains were lifted from a trough of mud 40,000 feet deep; and who can say how deep was the sediment that filled the floor of the ancient Tethys Sea, and was elevated into the Himalaya Mountains?

The hills are shadows, and they flow from form to form, and nothing stands

The Cambrian rocks of Wales were once rocks in a vanished land that must formerly have filled the greater part of the North Atlantic Ocean. The land melted away into ocean mud; the ocean mud rose in time as the Cambrian rocks.

Mud, mountains; mountains, mud — that seems to be the rhythm of nature. And Mother Earth seems to amuse herself making mud-pies and washing them away again. It may be difficult to believe that massive rocky mountain ranges can be washed off the face of the earth in this way, yet washed off the face of the earth they certainly are; and modern estimates of the work done by rivers prove that the process, geologically speaking, is not a very slow one. The Mississippi lowers its basin one foot in 3840 years; the Rhone lowers its basin one foot in 1528 years; the Po lowers its basin one foot in 729 years. Taking an average rate of one foot in 3000 years, Europe would be worn down to sea level in three million years; and in ten million years, provided that there were no upheavals in the meantime to raise the sediment, all the other continents that are now visible on the earth would be under water. Thus do rivers

Draw down Æonian hills, and sow
The dust of continents to be.

Proofs of the up and down of land areas are innumerable. Almost all dry land we know once formed an ocean bed. London is built on clay, which contains remains of marine shell-fish, such as the nautilus, and which must have been originally deposited under the sea as mud. Below the clay is chalk, which contains multitudes of such marine remains.

Have the beds of mid-ocean been lifted up and down?

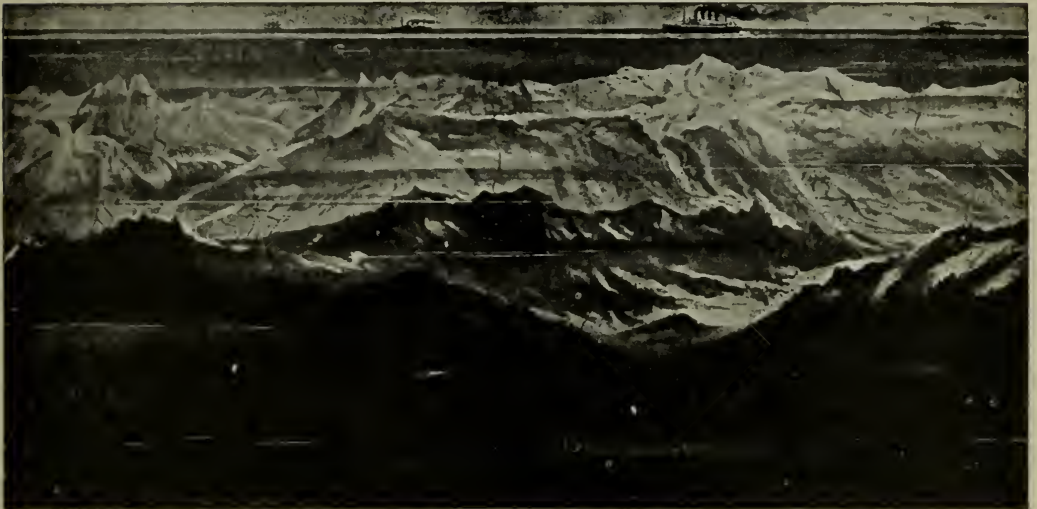
In Claiborne, Alabama, on the river of that name, there are found within a distance of only a few miles many hundred distinct species of the fossilized shells of molluscs, radiates, and other marine animals. Everywhere, in fact, remains of marine animals are found — on the Alps at 8000 feet, on the Andes at 14,000 feet, on the Himalayas at 16,000 feet.

Whether the great basins of mid-oceans have likewise moved up and down is a moot question. On the one hand, we find that sediment from the land flows into the great seas for only a limited distance — a hundred miles or less — and that all the

THE GREATEST HEIGHT AND GREATEST DEPTH



HOW MOUNT EVEREST, 29,000 FEET HIGH, WOULD LOOK IN THE DEEPEST SEA, 31,600 FEET



HOW A GREAT OCEAN LINER MIGHT SAIL OVER THE ALPS IF THEY WERE SET IN THE ATLANTIC

The land is not so high as the sea is deep. The average depth of the sea is 13,000 feet; and if the highest mountain were set in the deepest sea it would sink out of sight as shown here. If the Alps were set in a particular part of the Atlantic, the biggest liner might pass over them on its way to Europe.

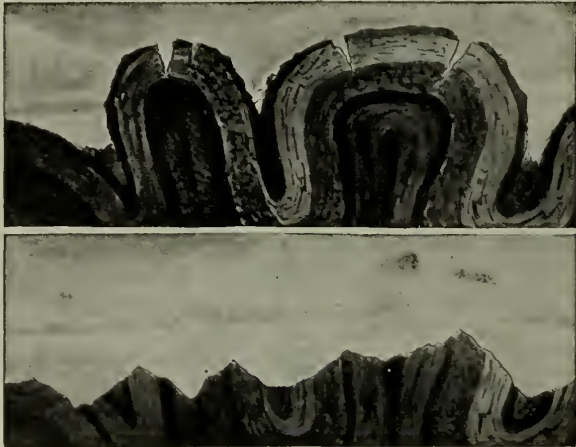
sedimentary rocks we know are made of such sediment, do not show special characters of deep-sea oozes, nor the sharks' teeth and whales' earbones, which are always found in the abyssal depths; also we find that the amount of salt in the sea tallies with the amount that the known sediments would provide, and gives no indication of unknown sediments from vanished oceanic continents, so that if ever there were continents in mid-ocean they were certainly not washed away.

On the other hand, the distribution of plant and animal life suggests that certain islands and continents now separated by deep sea were once continuous. Arguing from the similarity of animal life, some authorities maintain that India and South Africa, Madagascar and the Seychelles Islands, were once continuous across the Indian Ocean, and that the land was broken up into islands, some of which are still marked by the coral atolls of the Laccadives, Maldives, and Chagos archipelagoes, and by the Saya de Malha Bank. And there are similar indications that New Zealand, Australia, and South America were also continuous within the time of man. On the whole, it seems probable that "continents indicate regions over which land has dominated since very early days, and that the profounder depths of the ocean basins mark the center of larger areas, which have been even more persistently submerged."

Leaving now the question of the fashioning of the earth's crust, let us look for a moment at the finished product.

We find that now three-tenths of the earth's surface is dry land, and seven-tenths water. The greater portion of the land occurs in the great masses known as

the continents of Asia, Africa, North America, South America, Europe, and Australia. The average height of the continental land is about 2100 feet, but Mount Everest towers 29,000 feet, and some peaks of the Andes reach over 22,000 feet. But the land is not so high as the sea is deep. The average depth of the sea is 13,000 feet, and its greatest depth about 31,600 feet. If we were to plant Matterhorns here and there in the deep seas, in most places they would just appear above the surface; and if we were to plant Mount Everest in the deepest spot, it would sink far out of sight. And yet the irregularities of the earth's surface are really very small.



THE MAKING OF THE ALPINE PEAKS

These pictures suggest the way in which the great Alpine peaks have been made. The crumpling up of the earth would thrust up great heights of rocks, and the influence of the wind and rain and sun would wear away the softer rocks faster than the harder parts. We know from the position of certain layers that some of the great peaks which fascinate climbers must have been weathered into approximately their present shape in this way.

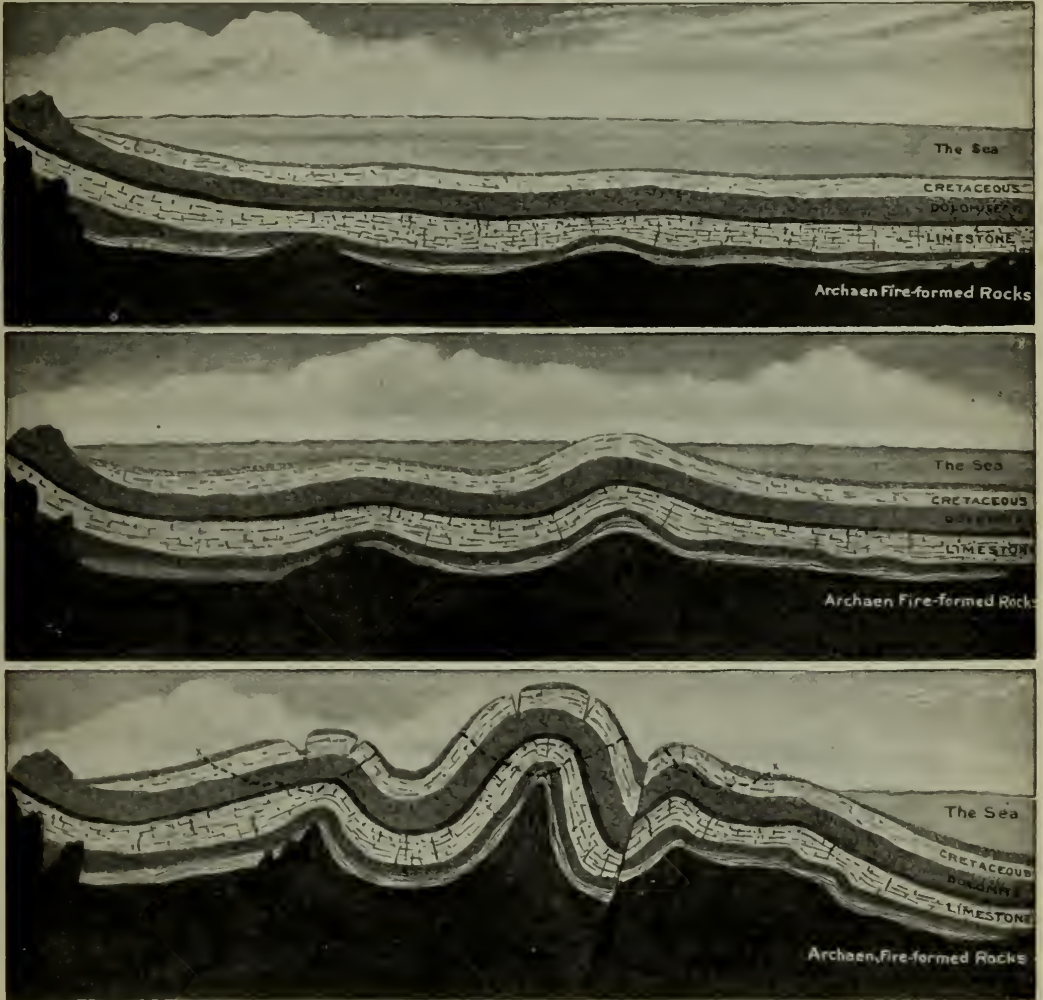
Big as the mountains are, and deep as the sea seems, it must never be forgotten that, compared with the huge bulk of the earth, they are little more than slight reliefs. A wet apple will have more water in proportion to its size than the earth carries in proportion to its size; and a midge on an apple would represent the size of the Himalayas on the surface of the world.

Professor T. G. Bonney supposes a globe of the radius of the dome of the Capitol at Washington made to represent the earth. On this scale, correctly proportioned, "the peak of Mount Blanc would rise less than half an inch above the original level, the summit of Mount Everest itself would not be quite nine-tenths of an inch above it, and the ocean would be lodged in a shallow depression, much of which would vary from half an inch to an inch in depth." On a globe two feet in diameter, Mount Everest, made to scale, would rise about seventeen-thousandths of an inch, and a scratch three-hundredths of an inch deep would represent the depth of the deepest sea.

There is a story told of a Scot who argued that his country would be bigger than England if it were rolled out flat! But mountains are very deceptive things, and even the Alps rolled out flat would only extend the Swiss frontier about seventy miles; and if, instead of being rolled flat,

Altogether, about eighty chemical elements are found in the crust of the earth, but only sixteen are found in any great quantities.

The favored sixteen are the following: oxygen, silicon, carbon, sulphur, hydrogen, chlorine, phosphorus, fluorine, aluminum,



WHY SHELLS MADE ON THE BED OF THE SEA ARE FOUND ON THE HEIGHTS OF THE ALPS

These three pictures represent an ideal section through the Alps, simplified to show how the mountains arose from the bed of the sea and acquired their present characteristics. The top strip shows a series of layers of sedimentary rocks beneath the sea; the middle picture shows the gradual rise throughout the ages; and the bottom picture shows the bending and doubling of the rocks through the contraction of the earth, as well as the effects of weathering, which has worn away parts, indicated by the dotted line. This emergence of the mountains from the sea explains why we find sea-shells on the Alps.

they were spread equally over Europe, they would increase the average elevation of the continent by only twenty-two feet.

To such contours, then — continents and seas, plains and mountains — has the earth been fashioned. Let us now see of what kind of stuff its crust is made, and how the stuff is laid on.

calcium, magnesium, potassium, sodium, iron, manganese, barium. These elements make up ninety-nine hundredths of the earth's crust; other elements, such as gold and silver, and zinc and tin, and iodine, forming the remaining hundredth. Let us look at some of the more important elements,

Of all the elements, oxygen is the most abundant; it forms about 23 per cent by weight of the air, about 89 per cent of water, and about 47 per cent of the rocks in the crust. At ordinary temperatures, in its free condition, it is, of course, a gas — the gas that causes combustion and is essential to the phenomena of life. In the earth's crust it is found in combination with other elements forming solids.

The element next in abundance is silicon, which forms about 28 per cent of the earth's crust. Combined with oxygen, it forms a mineral called silica, which forms about half of the known crust and serves to bind all the others together. It is seen best in the form of quartz. Apart from the function it plays in world-building, it is of inestimable importance to man as the basis of glass. Without silicon, no glass; without glass, no microscopes, no telescopes, no spectroscopes; and without these wonderful instruments how little would man know of the world — of "the boundless inward of the atom, boundless outward of the whole!"

Next comes aluminum, forming 8 per cent of the crust. It occurs chiefly in union with silica as the so-called "aluminum silicates," and is found in many rocks and clays.

More interesting, however, than any of these is the remarkable substance carbon. In the form of carbon-dioxide gas, it forms 1-2500th part by weight of our atmosphere. In solid form we know it as charcoal, black-lead and diamonds. In combination with hydrogen, oxygen, nitrogen, and sulphur, it forms coal. It is the fundamental element of organic life; without it, the world would have neither plants nor animal life.

One other elemental constituent of the earth's crust may still be mentioned — calcium, or lime. Calcium comes naturally after carbon, for it is in association with carbon, as calcium carbonate, that it is chiefly found. As calcium carbonate, or limestone, it forms 4 per cent of the earth's crust, and its occurrence therein is of the greatest importance to life, as without it there would be neither bones nor fertile soils.

Such, then, are a few of the most important elemental constituents of the earth's crust. The very interesting fact has been pointed out that with one or two exceptions the elements essential for the construction of living protoplasm are just the elements most abundant in the crust, as seen from the following comparative table, given by the late Sir Joseph Prestwich and modified according to the later percentages published by F. W. Clarke.

ELEMENTS IN PROTOPLASM IN ORDER OF THEIR ABUNDANCE	ELEMENTS IN THE EARTH IN ORDER OF THEIR QUANTITY PER CENT
1. Hydrogen	1. Oxygen . . . 47.02
2. Carbon	2. Silicon . . . 28.00
3. Oxygen	3. Aluminum . . . 8.16
4. Nitrogen	4. Iron . . . 4.64
5. Sulphur	5. Calcium . . . 3.50
6. Iron	6. Magnesium . . . 2.62
7. Phosphorus	7. Sodium . . . 2.63
8. Chlorine	8. Potassium . . . 2.32
9. Sodium	9. Titanium . . . 0.41
10. Potassium	10. Hydrogen . . . 0.17
11. Calcium	11. Carbon . . . 0.12
12. Magnesium	12. Phosphorus . . . 0.09
	Other elements . . . 0.32
	100.00

Geologically speaking, then, the earth's crust is composed of the elements we have named, compounded into hard material known as rock; and rock, in geological parlance, includes all the material of the crust, whether in massive pieces or in tiny particles. Granite is rock, but equally salt, soil, and sand are also rock.

According to their history and character, rocks are usually classified in two principal families — igneous, or eruptive rocks; and aqueous, or sedimentary rocks.

All rocks, in a sense, are igneous rocks, for all rocks were once in a molten condition; but the term "igneous," as a classifying term, is reserved for rocks which show signs of fusion; while the term "aqueous" is the term applied to rocks which have been broken up by wind, water, and frost, and strewn in layers on the surface of the earth. The term "sedimentary" is also applied to rocks formed by the deposit of substances in solution — as salt, for example — and to rocks formed by the deposit of organic remains, as coal and chalk.

Igneous rocks are probably in most cases forced towards the surface by volcanic action. We find them intruded into sedimentary rocks and inserted between their strata; and from the condition of the surrounding sedimentary rocks they have evidently been intruded when at a very high temperature. When they escape at the surface they show as lavas and other volcanic rocks; but when they fail to reach the surface, and have to cool down under deep layers of sedimentary rocks, they acquire a crystalline character. Granite, for instance, is an igneous rock that cooled in the heart of sedimentary mountains, and is laid bare only after ages of erosion.

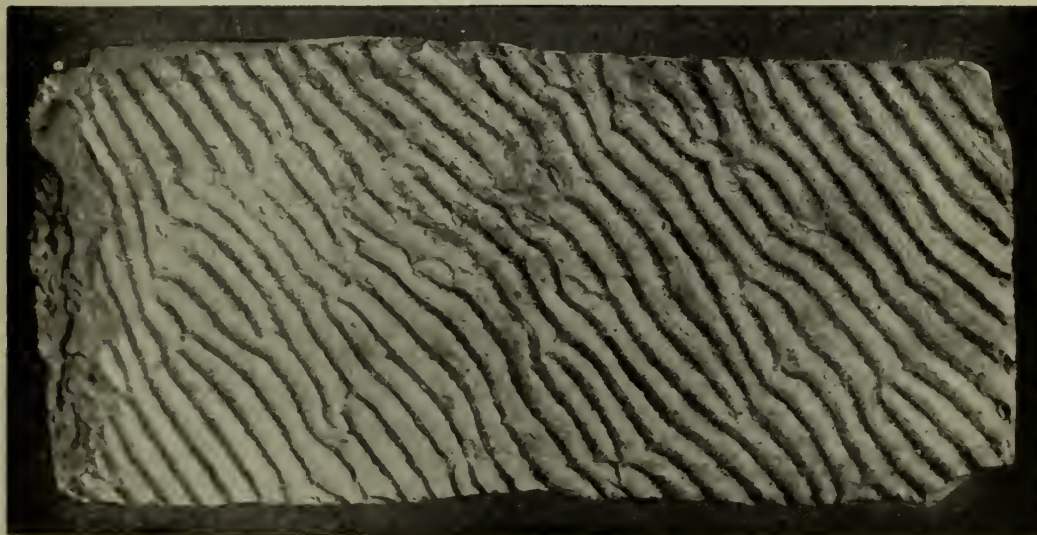
Sedimentary rocks are in layers, as might be expected, since in the process of this formation layer is deposited on layer. If the layers are thin, they are known as "laminæ," and the rocks are said to be laminated. If the layers are thick, the layers are known as "strata," and the rocks are said to be "stratified." Layers can be distinguished from each other only when there have been periodic changes in the size or character of the deposited material. A stratum may, of course, contain laminæ, and in such cases the strata may be compared to books laid one above another, and the laminæ to the leaves of the books. Sometimes it is very



FOOTPRINTS ON THE SANDS OF TIME

These footprints mark the track of an animal that roamed the world before the days of men. They are the impressions of the foot of a prehistoric creature made in mud which dried up rapidly in the sun and were thus preserved in a layer of rock.

difficult to make out layers at all, and this condition obviously indicates a gentle and steady depositing; whereas strata distinctly differentiated indicate variable currents, with sediment varying in quantity and quality. As layers are usually deposited under water, it is not unusual, especially in the finer sandstones, to find ripple-marks. In other cases, where the sediment has been exposed to air and sun, sun-cracks — such as one sees in sunbaked sand — are shown. In other cases, rain-marks, fin-marks, footprints of animals, and worm-tracks are visible.



RIPPLES OF THE SEA ON THE BEACH OF A MAN-LESS WORLD

Long before man came into the world the waves rippled over a beach of mud; the mud dried so hard in the sun that the marks of the waves were not washed out by the next tide; and, a new layer of sediment sealing them up, the marks of the ripples are preserved for us today, actual images of a world in which man did not yet exist.

What "faults" are and how they occur in sedimentary rocks

Sedimentary rocks, as we have already seen, have been elevated from the floor of the sea by the pressure of the contracting crust. They are laid down in flat layers, but the pressure naturally disarranges and crumples, and may fracture them. They are almost inevitably displaced from the horizontal, and the degree of displacement is known as their "dip." When the strata are torn, the ends are apt to be displaced like those of bones in a badly set fracture. This displacement is known as a "fault."

The two opposing faces of a fault may be displaced to greater or less degree. Sometimes there is very great displacement. Thus, near Sedburgh, in Yorkshire, there is a fault estimated at 5000 feet, and there is a displacement in the Appalachian Mountains that has been estimated as no less than 20,000 feet. Great faults like these were probably produced by progressive displacement.

What the loss of heat to igneous and water to sedimentary rocks does

Strata are not only bent, tilted, fractured by lateral pressure, but they are also worn away by such natural agencies as frost, wind, rain, rivers; so that, instead of presenting a curved surface, they may present edges and angles. The edges of strata which appear at the surface are known as their "outcrop," or basset.

Both igneous and sedimentary rocks show splits called "joints," which are caused by shrinking through loss of heat and water. In many cases hexagonal splits occur and hexagonal columns are formed, such as are well seen in Fingal's Cave, in Staffa, and in the Giant's Causeway, in Antrim. The splits take this hexagonal form simply because when "a mass is subjected to a uniform strain, the cracks, according to the law of least resistance, tend to assume a hexagonal form," or, as Bonney puts it, because "nature, in producing an effect, avoids the mistake so common among fussy folk, and does not expend more energy than is necessary." Some rocks which have been deposited

for a long time have been so changed in their structure by water, pressure, and heat that it is impossible to decide with certainty whether they are igneous or sedimentary, and rocks of this doubtful nature are usually termed "metamorphic." Many such rocks have a foliated structure; that is, they show a peculiar parallel disposition of the minerals which compose them. Examples of metamorphic rock are seen in gneiss, mica-schist, serpentine, and statuary rock.

Historic interest in the testimony of the sedimentary rocks

When we take a general view of the crust of the earth, nothing is more striking than the tremendous amount of sedimentary rocks that enter into its composition. Here and there are intrusions of igneous rock, but everywhere are tremendous sedimentary deposits — deposits which attain a maximum thickness of no less than fifty miles.

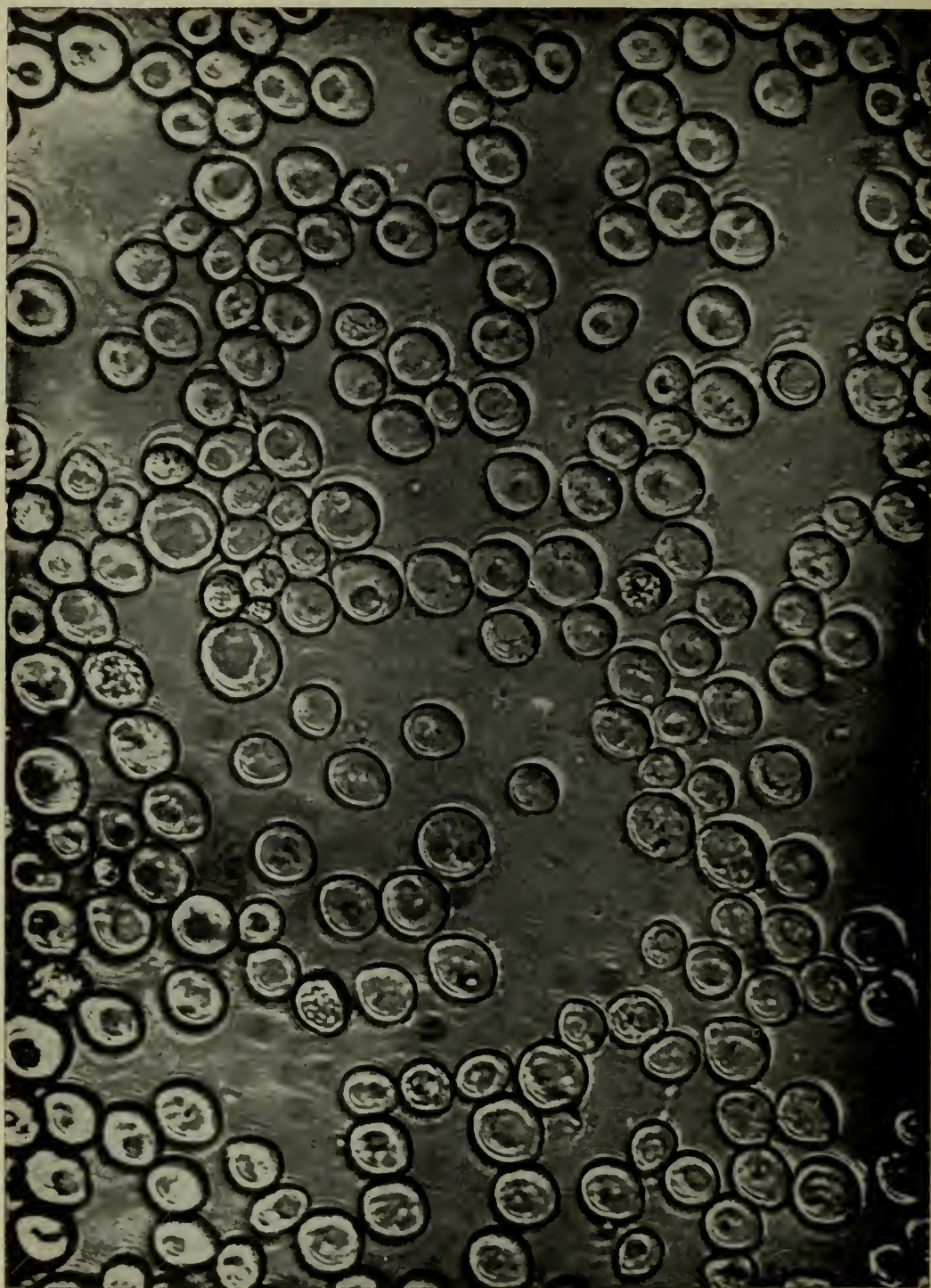
These rocks afford the most interesting study for the history of our earth. For in them is preserved, far better than in any historical archives, the memorials of the development of our globe from the remotest times to our own days; and above all, in the numerous fossil remains conserved in their strata, we see the wonderful races of plants and animals that once peopled our world. But the crust of the world is not a finished book yet. Still the rains pour, and the rivers flow, and the waves beat. Still the mountains are washed away, and still the rocks become mud. Still on the floors of the ocean sediment accumulates; and who knows but that one morning there will be a mighty cataclysm, and, behold, a new mountain range! The earth's crust is not so pliable and plastic as it used to be, but still mountains may be in the making in the depths of the sea. Who could have foretold that the ancient Tethys Sea was conceiving the Himalayas in its womb? And who can guess what mountainous surprises the oceans of the world may yet hold? Slowly, imperceptibly, the old continents are worn away, but the rise of a new continent may be as sudden as an earthquake.

AS FAR AS LIVING THINGS CAN ROAM



From the height of Mount Everest, 29,000 feet above the sea-shore, to the depth of the deepest sea, 31,000 feet below the sea-shore, life can exist, and within this range of eleven miles all known life is lived. To these extremities the earth reaches up and down, yet human life is lived, normally, within a fraction of this distance which separates the highest mountain peak from the blackest ocean depth.

THE NEAREST THAT WE CAN GET TO LIFE



The energy by which the warmth and all forms of vital activity of living things are sustained is furnished by the union of oxygen with portions of the protoplasm of the living cell, brought about through the agency of ferments produced by the cell itself. This picture shows (highly magnified) cells of the yeast plant, which in growth and multiplication produce a ferment that is the real cause of the "rising" of bread.

THE VERY HOME OF LIFE

A Peep into the Wonder-house in
the Structure of Living Things

THE CELL—THE UNIT OF LIFE

ALL living things, if we leave out of consideration those peculiar organisms known as "slime molds" where the units are fused, consist of units called "cells," and the living cell is therefore known as the unit of life. Yet this assertion requires the novel qualification that we now have apparent evidence of living beings, such as may cause certain diseases when they invade our bodies, which are so small that we cannot see them, and therefore cannot say what they are like. But with these exceptions all living things, from the smallest that can be discerned by the highest powers of the microscope, up to the largest whale, consist of cells.

Many consist of only one cell, which is the whole individual, and among these "unicellular" creatures are all the bacteria, many other minute plants, and many forms of animal life as well. But all the plants and animals which have passed beyond this first stage consist of many cells joined together, and are therefore called "multicellular." The meaning of "many" in this connection may be gaged from the fact that more than six millions of cells may be found in a drop of human blood equal in size to two pins' heads.

When we speak of a cell we usually mean a closed space, which may be empty or not—as a prison cell or a cell of bees' wax. When we speak of a cell of this character the wall, or boundary, is the essential thing. The word "cell" was applied to the units of living bodies because the wall was at first supposed to be their essential part. Cells were first discovered rather more than a century ago in plants, the

cells of which usually have very marked, strong, and thick cell walls. The discoverers supposed that these walls were the vital thing, and so they spoke of cells. Sometimes, as they saw, the cells were filled with something; sometimes, as often happens when plant cells are prepared for examination under the microscope, the cells appeared to be empty, their contents having dropped out.

But it was only somewhat less than a century ago that the real importance of the discovery was realized, and the cell theory of living things first formulated. Later study showed that what was true of all plants was also true of all animals, though the outlines of the cell and the cell wall are usually less conspicuous in animals. And later still it was found not only that the bodies of all the higher animals and plants consist of cells, but that they have each of them sprung from a single cell. The reader's body was thus once a single living cell—the most marvelous thing in the known universe.

But we cannot learn anything more about the cell until we correct the old view, which thought that the wall *was* the cell, as the walls are the cell of the honeycomb, or the cell of the hermit crab; and that the contents were just the food or the packing, so to speak, of the living being. We understand how the mistake arose, and we need not change the name which expresses the mistake. Nowadays we know that the contents inclosed by the wall is the essential thing; and when we talk of "cells" nowadays, and when men found scientific institutions, for the study of nothing but cells—the science is called "cytology"—

they really mean the *contents* of the inclosed space, not the wall inclosing it. Indeed, we now know many forms of living tissue in which there are no cell walls at all, and therefore the word "cell" is really inapplicable. But the contents are there, and they are the vital thing.

They are vital indeed, for they are alive. The cell contents are the living substance, "the physical basis of life," now known as "protoplasm." When we study cells, therefore, we study the protoplasm composing them; and that is the study of life as nearly as man can approach it from the physical side. Yet the cell wall deserves a word or two before we proceed to consider the living substance which the wall incloses.

Though nearly all animal cells, and even some plant cells, are devoid of such cell walls as first gave us the key to the cell at all, yet cells have membranes, or "skins," of some kind or another. For instance, a red blood cell is inclosed in a membrane which we cannot see, but which is certainly there, for the cell is elastic and returns to its shape after it is squeezed.

The exchange that a living cell makes with the world outside it

Even the amœba must have some kind of limiting surface to its body, though it may be more like the surface of the water in a full tumbler than anything else. At the very least all cells have surfaces; and, as all cells contain a large percentage of water, these surfaces, whether there be a thick, visible, frontier wall or not, must in some degree behave like other fluid or half-fluid surfaces. When we study the surface of a fluid such as water or mercury, and when we study the behavior of gases on two sides of such a surface — the air side and the water side — we learn that all sorts of extraordinary and peculiar things are capable of happening.

Now, within the last few years it has been realized that these facts — long familiar as regards membranes and fluid surfaces and so forth, quite apart from living things, and studied as a branch of physics — hold within them the key to many of the facts of the life of cells.

Will the key to the living world be found in the not-living world?

The cell is constantly making exchanges with the world outside it. It breathes, feeds, and excretes, takes in and gives out gases and liquids, and ever requires fresh supplies of water, and disposes of its old supplies. If these processes of exchange should cease, the cell must forthwith die.

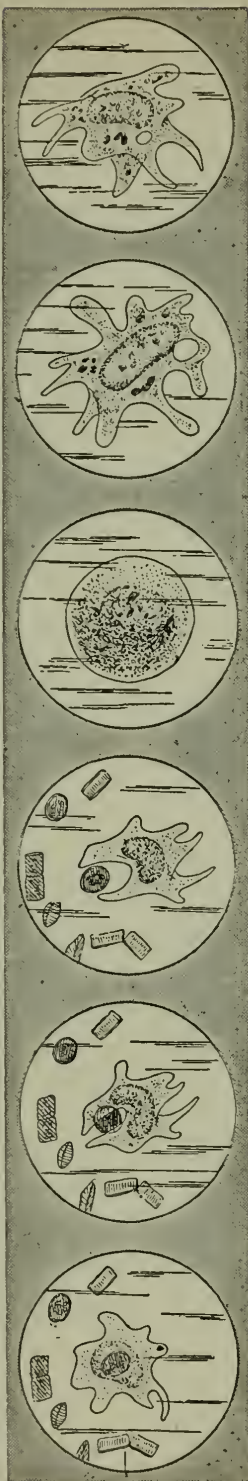
But the natural laws that govern the behavior of surfaces, or membranes, which are partly penetrable by gases or liquids or by both, apply in the realm of life as they do anywhere else: just as, say, the laws of gravitation or of motion apply to and within a tree or man as to a post or an engine. It is quite probable, therefore, that in a few years many of the problems of life, and of the processes by which life maintains itself not now understood, will be solved by the aid of the physicists, who bring their expert knowledge, derived from the non-living world, and begin to show how it contains the key to much of what happens in the world of life. There is a mechanics and a dynamics of the cell; and all the laws of what physicists call "surface-tension," and "capillarity," and "osmosis," and many more of these things, which students of life had hardly even heard of, will teach us to understand *how* the cell manages to breathe, and drink, and feed.

The knowledge that future generations may gather about protoplasm

Nay, more: these laws of physics — which men have hitherto studied in the behavior of mercury in a tube, or of the surface of water when a stick is pushed into it, and so on — these may help us to understand even how the cell moves, and how it absorbs gases into itself, and so finds its food, and avoids its enemies. All this subject is too undeveloped and difficult for us to discuss at present; but while we put the cell wall in the background, and correct the first observers who thought the wall was the important thing and the contents negligible, we must remind ourselves of what passes to and fro through it, and not unduly forget its existence.

Inside the cell is the protoplasm, and here we are in the very holy of holies of life. No fact of protoplasm can be too minute for our attention, and no degree of study can be excessive. Books may easily be devoted to our present knowledge of it, but we do not yet know one hundred-thousandth part.

We must use every means of study. The microscope must be pushed to its limits. Chemistry must teach us the composition of protoplasm. All manner of stains and dyes must be applied to cells in order to pick out details and structure otherwise invisible. Cells must be studied in life and in death, and in the process of dying. The movements of their protoplasm, inside them, must be watched, such as the streaming movements of the protoplasm just inside the wall of many plant cells, the crawling movement of the amoeba, the kind of dancing movement inside the malaria-parasite, and so forth. Every kind of protoplasm must be studied—which alone is a task for generations to come, since every living species is believed to have a different kind of protoplasm—and then every kind of protoplasm must in turn be studied in every variety and condition—when it is cooled and heated; when it is starved and gorged; when air is denied it, and when the pressure of air is raised; when it is put into oxygen; when alcohol or chloroform is administered to it; when light pours on it; when electricity is passed through it, etc. The field of study is literally infinite. Consider that chemistry makes daily new compounds, each of which acts in certain ways on protoplasm, and in different ways on different kinds of protoplasm, and this



THE SIMPLEST ANIMAL

These pictures show how an amoeba changes shape; and also how the amoeba feeds, throwing out parts of itself to pick up tiny or little specks of food.

one fact alone will show that there can never be any end to our study of living matter and its behavior. Here, then, we do not hope to learn all about protoplasm, but we may make a beginning.

Cells vary widely in their shape, and size, and structure, according to the species they belong to, and the part they have to play in the life of the body. But on the whole there is a type to which they conform, and that type is well represented by such cells as the amoeba, or the white cells of our own blood. The amoeba consists of a single cell, and is the humblest of known animal creatures; our white cells are tiny parts of the highest form that life has attained.

These are not by any means the simplest of known cells, but they are typical complete cells, and all the higher forms of life are derived from cells comparable in structure to these. We might have chosen such cells as those which constitute bacteria, or the red cells of our blood. These would be simpler. For instance, they do not contain a most important and vital part of most cells, called the nucleus. But this simplicity is only apparent. Bacteria are regarded as degenerate cells; and represent a fall and defect, as compared with perfect cells, which can live as plants should do. They are therefore not typical. The red blood cell is not degenerate in the same sense, but its simplicity is also deceptive. Young red blood cells have a nucleus, but as they mature they lose it, and give up many possibilities of their lives in order to devote themselves wholly to their mechanical task of portage in the blood. They also are therefore not typical.

The typical cell, such as the amoeba or one of our white cells, consists of two parts, a nucleus and the rest of the cell outside the nucleus, known as the "cytoplasm." Though the greater part of the cell usually consists entirely of this cytoplasm we definitely know that the nucleus is the more important part. We may say that it is all-important, as we shall see. But the rest of the substance of the cell is undoubtedly alive. It is living protoplasm, and it shows the characters of protoplasm in their very simplest form. The nucleus is also composed of living protoplasm, but here a higher stage has been reached. If, therefore, we desire to study living matter in the simplest form we can discover, we must study the cytoplasm.

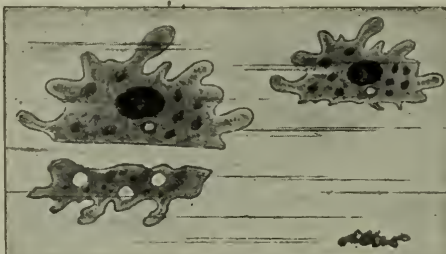
Naturally, the first question which the microscopist asks, as he looks through the best instrument he can obtain, is what structure this portion of the protoplasm displays. Often it looks granular. Sometimes there seems to be a sort of network. At other times, and with other methods of preparation, it seems to have a structure resembling foam. Controversy on these appearances has been chronic for many years, but here we need not attempt to decide between them. Protoplasm does certainly seem to have some sort of structure, under the microscope, but probably this structure varies at different times; and it may be that the appearances of a network or of a "foam-structure" are only those of dead protoplasm, not of the living stuff which we seek to understand. We are here traveling far beyond the limits of what the microscope can reveal, and other methods are necessary.

Chemistry gives us the aid that we seek. First, we find that protoplasm contains water, and that all living protoplasm consists of water to the extent of about three-quarters of its weight. The remaining quarter is not so easy to describe. It is, of course, so far from being a simple substance, as the name "protoplasm" might lead us to suppose, that it is really an ever-changing and incalculable mixture, blend, and combination of a vast number of complicated substances called "proteins," which no chem-

istry yet can unravel. What we call "protoplasm" includes all these things. But though they defy description, we can at least definitely assert that certain elements are always found in protoplasm. They are carbon, nitrogen, oxygen, hydrogen and sulphur. Some others are probably necessary, such as sodium and chlorine, combined to form sodium chloride, or our common salt, which appears to play a necessary part in all life. But the five first named are absolutely essential. It is particularly to be observed that these elements, necessary for life, are not rare but common, widely distributed throughout air, land and sea. And it is no less noteworthy that protoplasm displays to the chemist no element whatever with which he is not perfectly familiar elsewhere. It is crowded with special compounds, met nowhere else, though the elements of which they are compounded

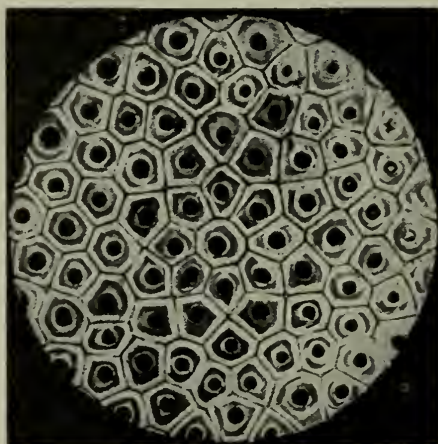
are nothing more or other than certain of those very elements which make the earth, the sea, the sun and the stars.

When protoplasm is further analyzed, we find that it includes, in addition to the proteins, which are the essential constit-



THE THING WITHOUT WHICH A CELL DIES

No nucleated cell can live without its nucleus, packed with nucleoplasm. If a cell can be divided so that the nucleus is cut away from one part, that part will die.



IMITATIONS OF LIFE-CELLS

Parts of an artificial product made in a laboratory, showing how closely cells of life can be imitated in artificial structure.

uents of protoplasm, such compounds as salts, starches, sugars, oils, etc. When we kill protoplasm these are the separate groups of things which we get out of it. If we suppose, however, that they exist, just mixed together, in living protoplasm, as the ingredients of a pudding are mixed, we lose any chance of understanding how protoplasm lives. If we could only have the opportunity once to actually analyze living protoplasm — which is impossible, for we must murder to dissect — we should doubtless find that these various compounds exist in a sort of still further compoundness with each other.

They are somehow so much more than merely mixed or packed together that they can exchange atoms and groups of atoms among themselves, in a fashion which no chemist can imitate in any of his experiments. It is this unique capacity for rapid, various, reversible, chemical change and interchange that marks the chemistry of protoplasm. It is the most unstable substance in the world; and if it ceases to be unstable, ever changing and liable to change, it dies. Again we learn the truth that to live is to change.

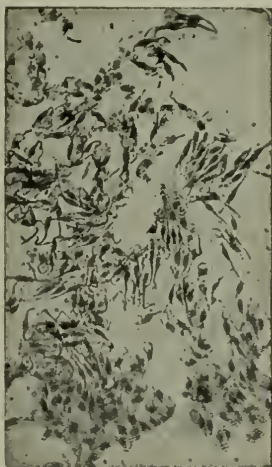
One more fact about the chemistry of protoplasm is essential. When at all active, it is always burning away, and therefore it always requires oxygen. In one word, it breathes; and every living, active cell breathes continuously or dies.

Some remarkable experiments by French scientists suggest that this breathing may sometimes be made very slow indeed, if not even suspended, so that the living cell may almost cease to live for a time, but will resume its life and breathing when water and a suitable environment is supplied to it. Here is the explanation of the germination of dried seeds which may be a century old. But these cases where

life seems temporarily suspended or relaxed are just the exceptions which prove the rule. The seeds cannot go on breathing, because the indispensable water, the medium of all the chemical changes of life, is absent. Supply the water together with other indispensable conditions and life starts again. Nothing in modern research takes us farther into the hidden places of life than these experiments.

If protoplasm must take in oxygen and use it up in order to live, we must satisfy ourselves as to how this happens. The oxygen enters the cell, and reaches the protoplasm

within, by passing through the exterior of the cell; and we have seen that the physicists are helping the students of life to understand the forces which move the oxygen inwards. And now, we may suppose, it feeds the living flame, as we may metaphorically call it, just as oxygen feeds the flame of a candle or a fire. Though this is really just what takes place, it does not happen under the same condi-



TYPES OF THE CELLS THAT HUMAN LIFE INHABITS

Living things may be animal or vegetable, large or small; they may flourish in the lowest and blackest depths of the ocean, or upon the dizziest crag, but they all consist of cells, of which these are three types, taken from the human body. The lower picture shows fibers connecting nerve-cells.



THE EARLIEST FORMS OF LIFE OF WHICH RECORDS EXIST TODAY

This picture shows us the kind of animals that lived millions of years before the great coal-forests. At that time the waters covered the greater part of the earth, and were inhabited by trilobites and the ancestors of corals, cuttle-fishes and sponges.

tions. No living thing can exist at the temperature of a candle-flame; and oxygen under ordinary conditions will not combine with the materials of protoplasm at any such low temperatures as those of living things. Let the student of fuel, the automobilist, the aviator, the engineer, imagine a fuel which is three-fourths water and much more than dripping wet, and then imagine the task of getting it to burn at the temperature of one's skin.

Nowhere but inside living protoplasm can such an astonishing thing be done, and it can only be done because the burning or combustion, or union with oxygen, of protoplasm is a unique process, vastly different from anything that naturally occurs, or can even be produced by experiment, elsewhere. The protoplasm of the cell takes the oxygen into the living substance, and its combination there with certain protoplasmic products, whence comes the energy, warmth and movement of all living things, is effected through the vital activity of the cell. The living cells that compose any muscle, for instance, quietly live and breathe by using a little oxygen, so long as they are not called upon to contract. But they are able to hasten the rate of combustion instantly a thousandfold when a nerve gives the order, and the muscle-cells are set to work.

In this vital activity of the cell certain substances called "ferments" play an important part. A ferment, which is the product of a living cell, is an organic substance of which a very minute quantity is capable of inducing a considerable chemical change without itself being affected

or used up in the chemical reaction so brought about. It is maintained that certain of these ferments are the agents by which the cell produces those compounds that enter into combination with free oxygen in respiration.

Again, there are ferments in some kinds of protoplasm—those kinds found in the microbes, discovered by Pasteur, which cannot live in the presence of air—which are more wonderful still. These anaerobic bacteria live, away from the air, in substances such as beef-jelly, which consist of compounds containing oxygen. These compounds have to be broken up and decomposed, and the oxygen from these must be used for respiration by the bacteria if the bacteria are to live, and this is done by special ferments which are produced by the protoplasm of the bacteria.

The general protoplasm of the cell often contains all manner of things which are not part of it. They may be the remains of a feast, as when the amoeba is digesting a meal, or when a leucocyte is digesting a bacillus or a malaria-parasite. In other cases, the protoplasm may contain special products of its own creative power, such as the green pigment of chlorophyll which we find in the cells of green leaves, and which is there for the purpose of the plant's life. Also, the protoplasm may contain any number of kinds of foreign substances which have been administered to it, some harmless, but most of them poisonous. These are in the protoplasm, but not of it; and the same is true of many waste products of the life of the protoplasm, which it is in process of discharging.

The wonderful nucleus which is the center of the life of the cell

Let us turn now to the nucleus of our cell. It was formerly believed that many of the lower, unicellular organisms of both plant and animal worlds were destitute of nuclei, but improved methods of study have enabled us to show that this is not true, at least for the unicellular animals. Although no one has been able thus far to demonstrate positively the existence of a nucleus in a cell of the bacteria, nevertheless it has been shown that there are present in these cells, embedded in the cytoplasm, minute granules that behave under treatment with stains and reagents in very much the same manner as does the chromatin matter composing the nuclei of the more typical cells. As a result of these and other observations many cytologists are of the opinion that no cell (unless it be a degenerate, such as the red cell in the blood of man) is entirely devoid of chromatin material, even though a definite nucleus cannot be shown to be present.

The first fact we learn about the nucleus is that it is the center of the life of the cell, that at all times it plays an important part in vital activity and that the constructive and nutritive processes of the cell are dependent upon and closely associated with it. If any cell be cut in such a way that its nucleus remains in one portion and the other contains none of the nucleus, that other part will die. But the part which contains the nucleus will not die. On the contrary, it will make good its loss, and be none the worse. This extraordinary fact is true of all cells whatsoever. What we call "nerves" are prolongations of the cytoplasm of nerve-cells. The nerve which informs us when our shoe pinches is a prolongation of a cell — rather, of many cells — in the spinal cord, perhaps three feet or more away from our corns. The life of the nerve-fiber depends upon the nucleus in the nerve-cell, just as we see in the amoeba. If the nerve-fiber be severed, the part next the cell, which contains the nucleus, is none the worse, just as the protoplasm which is still connected with the nucleus of the divided amoeba is none

the worse. But the part of the fiber which has been separated from the nucleus in the nerve-cell immediately degenerates and dies, just like the amputated piece of the amoeba. The law that the nucleus is the center of the nutrition and life of the cell is therefore proved equally true of the lowest and highest types of nucleated cell — the amoeba at one end of the scale, and a human nerve-cell at the other. As we shall later see, cells divide, and when they do so the nucleus divides also — indeed, the nucleus always divides first — and thus each half of the cell has a portion of nucleus in it, and can live and complete itself.

Soon we shall devote ourselves to studying the supreme business of the nucleus, which is to divide and form new cells, and



ONE OF THE WONDERS OF LIFE

All cells must divide, as this is doing. The cell's surface is its "mouth," so that the division of the cell, and the *creation of more surface area*, is the only way in which the cell can obtain food enough as it grows. From this division of cells proceeds all the immense variety and the progress of life.

meanwhile we have noted the function of the nucleus in nutrition. But before we study its function for the reproduction of the cell, and for all that depends upon it, we must realize how cells are built up into individuals, and what becomes of them.

The lowest plants and animals consist simply of one cell each. In time the cell divides and forms two individuals, each consisting of one cell, as before, as we see in the picture on page 188. All the higher plants and animals, if their method of reproduction is sexual, begin their individual existence as one cell also, and that cell divides, just as the amoeba divides, but in this case the two daughter-cells stick together. They divide again and again, until we have a multitude of cells. Of these, if the species be a vertebrate, some turn into skin, others into bone, others into muscle and nerve; and, lo! here is a living animal.

The cell which gives rise to new individuals

All this depends on cell division, and, indeed, division is as much an essential and vital part of the cell's business as is its own individual maintenance. It lives to divide. This division is one of the most wonderful and mysterious facts in all science.

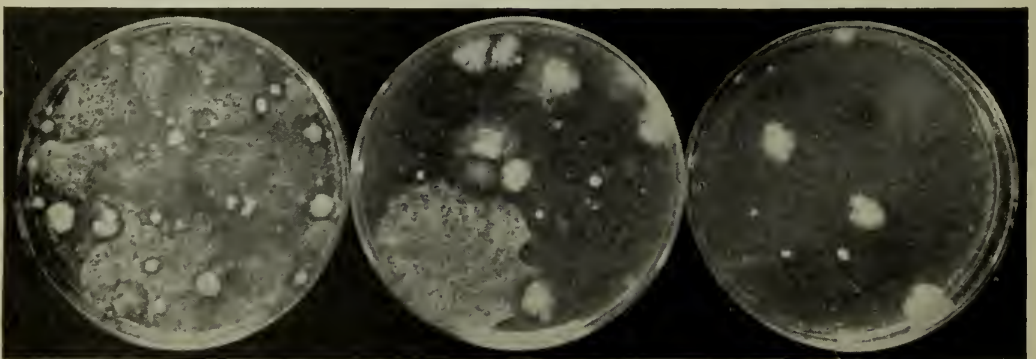
But why should a cell divide at all? Why should not an amoeba grow and grow indefinitely, without dividing? The whole face of the living world would be different if this were so; and we seek a reason for this elaborate, difficult, and dangerous business which the amoeba, and living cells of every kind and shape, undertake when one would think that, if they *must* grow, they might as well just grow bigger.

The answer is that cells cannot afford to grow too big. The biggest cell-bodies we know — not counting such protrusions as nerves — are very tiny. Herbert Spencer was the first to offer a satisfactory explanation. The bigger a cell grows, the greater is its volume, in proportion to its surface. A small marble, similarly, has much more surface in proportion to its weight than a big marble. Therefore the time comes when the cell has too much living matter in it for its surface to feed. Its surface is, let us say, its mouth, and, as it grows, its mouth does not keep pace with it. Let now this overgrown cell divide into two, and it at once gets much more surface — the surface of two new cells put together — through which to

feed and maintain the life of the same quantity of living matter. That is why all cells must divide, and why no cells ever grow beyond a very tiny size. The consequences of this simple fact are gigantic, for from cell division proceed all the variety and all the progress of the living world.

Lastly, we must note that no cell lives indefinitely. If it be an amoeba or a microbe, and even if it escape poisoning or starvation or other accident, such as all forms of life may encounter and succumb to, the time comes when it must divide or stop growing. To stop growing, *in one way or in another*, is to die. The cell obeys the law of life, which is to make more life; and rather than die of arrested growth and overnutrition it divides. In so doing, it in a sense ceases to exist. Nothing has died exactly, for there is no corpse. But the amoeba that was is not any longer. In its place there are two others which have grown from its halves.

As for the cells of those plants and animals which consist of more than one cell, they die also. It is literally true that many cells of our bodies die every day, and the body as a whole will die too. Before doing so, it may have renewed its life in its own wonderful way, just as the amoeba, before losing its own individual existence, renewed its life. But the fact of death remains; and our science of life will be very crude and useless unless we can somehow explain this fact of death. How can death, as an ordained and natural fact, be reconciled with this universal striving towards life?



From Lipman's *Bacteria in Relation to Country Life*, The Macmillan Co.

COLONIES OF SOIL BACTERIA ON AGAR, SHOWING THE EFFECT OF SUCCESSIVE DILUTION

By taking gradually decreasing quantities of soil for inoculation into a given quantity of gelatin the number of the colonies appearing on the plate may be made small enough to allow their unhindered development, and, likewise, their careful study and the recognition of the species of which they are composed.

HOW THE SOIL IS NAMED

An Inquiry into the Properties and
Peculiarities of Mother Earth's Mantle

THE PHYSICAL WONDERS OF THE SOIL

THE size of the particles of any soil is the all-determining factor in the outward or physical characters exhibited by that soil. Its appearance, its feel, the rate of air and water circulation, the ease of tillage and of drainage, are but a few of the conditions governed by the size of particles present. "Texture" is the term used to express this size of particle. Thus a soil may be coarse, medium, or fine according to the mixture of the different sized grains which make it up. Texture is of such importance in soil study and investigation that it has been utilized in the naming of soils wherever they occur. This method, based on the size of the particles which make up the soil, has nothing whatever to do with the origin of the soil, as does the system explained in the previous chapter.

As soils are made up of particles of different sizes a general term is needed which will not only give some idea of the texture of the soil but reveal at the same time some of the physical properties as well. "Class" is a term which is designed to supply this want. We may have any number of classes, depending on the different sizes and proportions of the sizes present. Class names have originated through many years of agricultural practice and have of late become more or less standard due to the necessity of soil study.

Soil classes may be divided into four groups: sands, silts, clays, loams.

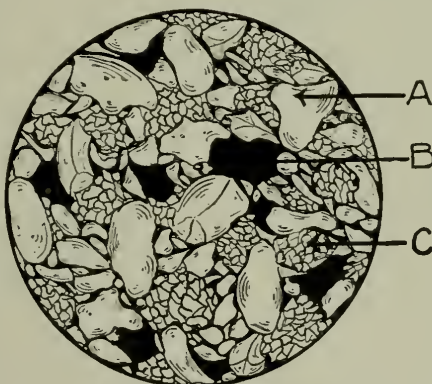
All of the particles in a soil that may be seen with the naked eye are called "sand." If a soil is made up largely of such sizes, it is of necessity a sand. We may have several kinds of sands, however, as coarse, medium, fine, very fine, gravelly, and stony.

Sandy soils are loose and open. They hold but little water and dry out rapidly. Air moves through them readily and they

are very easy to plow and cultivate. The drainage is always rapid. Their stock of total and available plant food, however, is usually low and they often need fertilizers carrying the three primary elements: nitrogen, phosphorus and potassium.

The particles of silt and clay are too minute to be seen with the naked eye. Their size can be judged better by feeling the soil between the thumb and fingers.

The smallest silt particle is two ten-thousandths of an inch in diameter. In other words, it would take five thousand of them laid side by side to make an inch! All particles below this size belong to the clays. If the silt grains are small, what would you say of the size of the clay particles? They are so infinitely small that figures give no idea! They mean nothing! Suffice it to say that the smallest clay particles cannot be seen through the highest power microscope.



From Lyon's *Soils and Fertilizers*, The Macmillan Co.

STRUCTURE OF LOAM SOIL

This diagram shows the structure of a loamy soil in good condition for plant growth. A, sand particle; B, pore space, occupied by air and water; C, granule composed of particles of silt and clay.

Silts and clays differ only in the size of the particles that make them up. To be sure, silts may contain some clay particles, and vice versa, but the majority of the particles belong in the class so designated. Silts and clays are sticky soils when wet, and hard when dry. They swell when water is added and shrink correspondingly when dried. While they can hold a large

amount of water they do not drain very well. Air cannot penetrate such soils readily. Clay possesses the above properties to a greater degree than silt due to the smaller size of the particles that make it up. We may have several kinds of silts and clays, such as gravelly, sandy, and stony. Silty clays and clayey silts also sometimes occur.

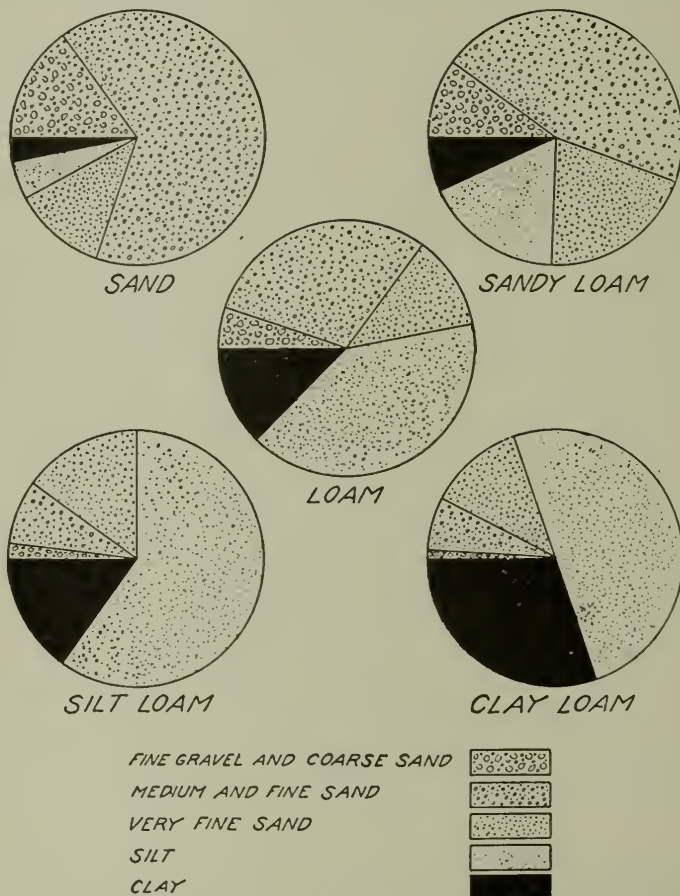
Due to the characters as above listed silt and clay are hard to cultivate. They are called "heavy" soils

as compared to sands, which are "light." They easily become cloddy and rough. They are likely to be very wet after a rain, due to the slow draining away of the water. The roots of the crops growing on such soils and the germs that populate them often suffer for lack of oxygen, due to the slow penetration of fresh air. In spite of all this these soils are rich. They contain plenty of plant food, and if the right

operations are applied this food can be unlocked. They are "strong" soils. Sands in contrast are soils "weak" in their natural crop-producing powers.

Sands, silts, and clays are soils that are made up of particles more or less uniform in size. These soils, while frequently found, are not nature's commonest product. If you think over the many forces

that are utilized in soil building and the many processes that the material must undergo, you must agree that "mixing" is what nature excels in. As a consequence soils are usually mixtures of many different sizes of particles. Such soils are called "loams." We may have many kinds of loams, depending on the size of particle which happens to predominate in the mixture. Thus there are gravelly, sandy, fine sandy, silty, clay, and silty clay loams.



From E. O. Fippin's *Tilth and Tillage*, Cornell Reading Course for the Farm, New York State College of Agriculture

Diagram representing the important kinds of loams and the proportion of the different sized particles making up each kind. The character of a soil is determined by the sizes of particles that make it up.

The ideal soil is most likely to be a loam. It combines all the desirable properties of sand, silt, and clay and yet possesses few of their bad points. Thus it works easily, drains quickly, and, like sand, affords plenty of air. Like silt and clay it has plenty of plant food and usually this is in an available condition. Our most fertile soils are loams. The diagram shows the composition of the important kinds of loams.

Number and surface of soil particles

While we are still considering soil particles let us speculate a little, for it is at best only speculation or guess, as to the number of particles which actually make up a given amount of the different soils. Will the number be large or small and what soil will contain the most? From what we have just discussed, the numbers must be very large. The soils in increasing order are sand, loam, silt, and clay.



From Lyon, Fippin and Buckman's *Soils, Their Properties and Management*, The Macmillan Co.

PUDDLED AND GRANULAR SOILS

The physical condition of a soil is a controlling factor in successful crop production.

Considering the particles of soils to be round, which we know is an incorrect assumption, certain calculations have been made to find the number of particles in a pound (about a pint) of soil. The figures are so large that we can scarcely realize what they mean.

APPROXIMATE NUMBER OF PARTICLES PER POUND OF SOIL

Sand	1,100,000,000,000
Loam	3,500,000,000,000
Silt	5,400,000,000,000
Clay	8,500,000,000,000

Besides giving us some idea of the host of individuals with which a farmer or gardener must deal, the number of particles serve another purpose, that of enabling us to calculate the aggregate surface exposed by a given amount of soil. The surfaces of the particles determine the action of the oxygen, carbon dioxide, and water. They govern the rate of solution and therefore the feeding of the plant. The amount of this surface is then very important.

Calculating upon the same soils as before, the following figures may be presented :

APPROXIMATE INTERNAL SURFACE OF SOIL

SOILS	SQUARE FEET PER POUND	ACRES PER ACRE OF SOIL ONE FOOT DEEP
Sand	280	22,000
Loam	1000	75,000
Silt	1600	125,000
Clay	2000	170,000

It is at once evident that the internal area of even a sandy soil is tremendous. It is clear now why with such an amazing surface exposed to the action of the water the slowly soluble soil minerals go into solution readily enough to supply the plant. It is easier to see why soils can hold so much water, why they can absorb fertilizers, why they can condense gases, and why they can compel the most difficult and complex chemical changes to take place rapidly.

The farmer in cropping an acre is really dealing with thousands of acres in one, this manifold character being one of the real causes of the fertility of the land.



From Lyon and Fippin's *Principles of Soil Management*, The Macmillan Co.

POOR TILTH A good seed bed is the first step in the production of a paying crop. IDEAL TILTH

Pore space of the soil

The average soil is loose, open, and friable, thus allowing ready air and water movement. The particles are not closely in contact, thus producing numberless minute spaces, as or more numerous even than the particles of soil. The aggregate or sum total of these connected openings is called "pore space." Soils vary in their pore space according to their compactness; the looser a soil becomes the greater is its internal space. Sands contain less space than clay, the general rule being that the finer the particles of a soil the larger the total pore space. An added rule is that while clay has more total pore space than sand its individual pore spaces are very much smaller. This accounts for the fact that water runs so rapidly through sand and so slowly through clay. The friction developed by the minute spaces in clay is the controlling factor.

You will be interested to know in general the pore space in ordinary soil and you will be surprised to find what a large proportion of the soil bulk is not occupied by particles at all.

PERCENTAGE OF PORE SPACE IN SOILS

Sand	32 per cent
Loam	35 per cent
Heavy loam	41 per cent
Clay loam	45 per cent
Clay	48 per cent
Heavy clay	53 per cent

It seems, then, that from one-third to one-half of our soils is pore space. What is this space occupied by and what is its importance? Water and air are found in this space in varying proportions according to conditions. If the soil is very dry, the air predominates, but if a heavy rain has just fallen the air is largely displaced by water. The relation of the total pore space and the size of the individual spaces to the amount and particularly the proportion of air and water present is very important. This balance governs the physical, chemical, and bacterial relations of every soil and consequently has much to do with the cropping capacity. In a soil of ideal condition for plant growth the volumes of air and water should be about equal.

The stickiness of soils

A clay soil becomes very sticky when mixed with the right proportion of water. It is plastic, can be worked into a very compact condition without falling to pieces, and on drying it becomes very hard. When in this condition it is said to be "puddled." Such a state is not favorable to life of any kind since air and water cannot move through such a soil when it is wet and plant roots cannot penetrate it when dry. If you have ever made clay marbles and dried them in the sun, you know exactly what is meant by this term puddled. A sand, on the other hand, cannot be worked into this state. You may handle it all you please. It remains in the same condition whether wet or dry. What is the reason for this? Why do sand and clay not respond the same? Is it due to the differences in the size of particles? This looks like a good guess. Let us see.

The particles of a sand are large and heavy. They will not stick together when dry and only slightly when wet. It is what is called a single-grained soil because the particles function separately and independently. As a consequence the soil is not sticky nor can it be worked when wet into a condition which is bad for plants. In fact sand is often too loose. Tilling it when a little too wet is often really an advantage.

Clay, on the other hand, has small particles which stick together easily, too easily, in fact. If this soil is plowed a little too wet, these minute grains slide over each other and come very close together. This is the puddled condition already described. The different properties of sand and clay, then, arise from the relative sizes of the particles which make them up.

Granulation of soils

As it is the heavy soils, such as the silts and clays, which are so likely to be in poor condition for plant growth, such soils should receive particular attention. Methods of handling have little effect on sand, but heavy soils are easily affected either for better or for worse. We must be careful. If a puddled structure is not desirable in a



From Fippin's *Tilth and Tillage*, Cornell Reading Course for the Farm, New York State College of Agriculture

GOOD PLOWING IS AN ART

The plow exerts its pulverizing action by the shearing stresses brought to bear on the furrow slice as it slides over the moldboard.

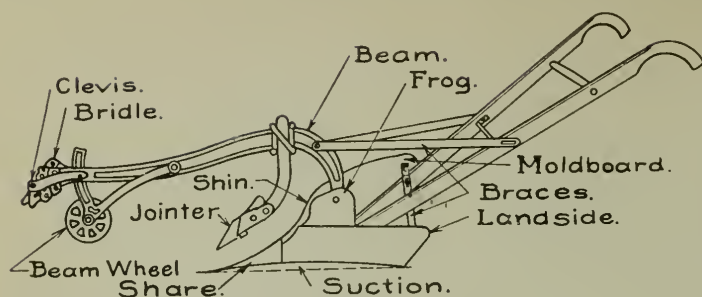
clay, what condition should be looked for? Evidently the soil should be loose and open. The arrangement of the particles which brings this about is called "granulation."

Granulation is really the redirection and control of the stickiness already spoken of so that numberless little crumbs or granules are formed. These can be seen with the naked eye. They are open, porous and light. They make the soil loose and friable. Plant roots can easily penetrate under such conditions. Water and air circulate readily, chemical changes are encouraged and conditions both for higher plants and for bacteria are made better. Examine some soil at your next opportunity and see whether you can distinguish this granular condition. The successful use of a heavy soil, then, depends on granulation. This crumb structure must be encouraged if we are to use our clays and silts for the production of crops for our animal and human population.

How crumbs are formed

The fact has already been emphasized that the forces of weathering are as active on the soil as on the original rock. Soils are affected in various degrees according to their natures. Clays, silts, and loams, while receiving the same benefits as sand, are in addition kept in a good physical condition. Puddling is counteracted. In other words, the crumb structure so necessary in such soil is partially maintained by the same forces that brought the soil into being. How these natural agencies act and how they are manifest may well be considered at this point.

The drying of a soil has been shown to draw the particles together, while wetting causes the soil to expand. These two actions, if they alternate and are often repeated, as they are in nature, tend to disrupt the soil mass and break it up into tiny fragments. Each fragment is, of course,



From McCall's *Studies of Soils*, John Wiley & Sons

PARTS OF A WALKING-PLOW

The setting of a plow to do good work demands practice and skill.

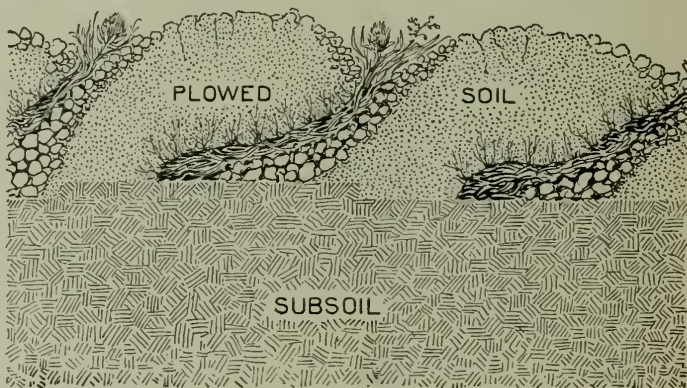
made up of many particles and is what is called a crumb or aggregate.

Freezing and thawing have the same effect since water expands with such a powerful force when it freezes. The alternate drying, wetting, freezing, and thawing that a soil undergoes in winter and spring have a marked influence on its granulation. The farmer makes use of such forces in fall plowing. He turns the furrows up and exposes the soil to the influence of climatic changes. The better seed bed possible to prepare the next spring and the increased productivity of the land argue in favor of such a practice. The reason therefore lies in the improved granulation.

Soils rich in organic matter are generally in good condition. The fact that organic

matter is loose and open partly accounts for this. Its tendency to break the soil particles into groups and to act as a binding for these groups must be recognized. Again because of the large water capacity of organic matter the disruption due to drying and freezing is encouraged. The maintenance of large amounts of organic matter

in the soil is one of the first problems of a successful farmer. This organic material may be obtained by adding farm manure or by the turning under of green crops



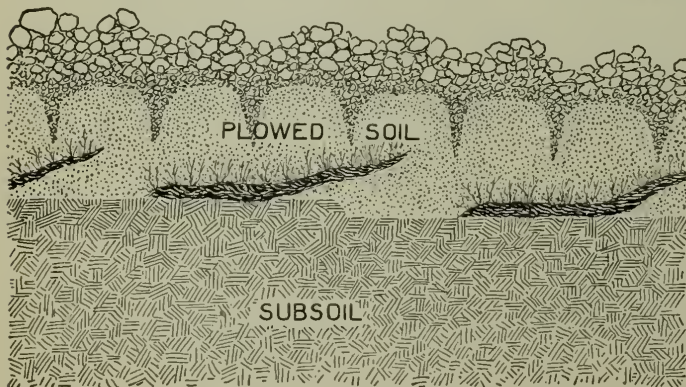
From Mayne and Hatch's *High School Agriculture*, © 1913, American Book Company

THE FURROW SLICE AS LEFT BY THE PLOW

The seed bed must now be made by surface tillage of the loosened layers of soil.

called "green manures." Even the roots and aftermath of the crops have some influence in this direction.

Lime when added to the soil, especially clay and silt, has a peculiar influence toward granulation. It causes the tiny particles to come together in clumps and irregular groups. As the action goes on granules are formed and the physical condition of the soil is much improved. Lime is added to the soil in amounts ranging from one to four tons per acre. On heavy soils it generally has a good effect, especially if the physical condition is not what it should be. We must not



From Mayne and Hatch's *High School Agriculture*, © 1913, American Book Company

THE SEED BED AFTER CULTIVATION AND PACKING

The plowed soil presents an ideal medium for the germination of the seed and should furnish the crop with plenty of food and moisture as the season advances.

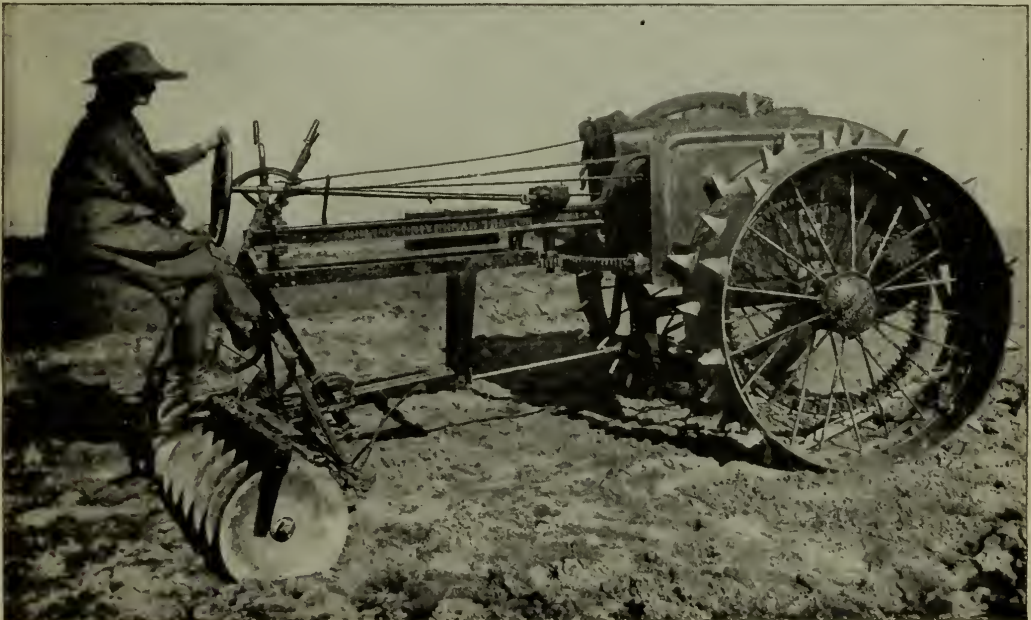
infer that this physical influence is the only benefit derived from the addition of lime. Sometimes the land is sour or acid and the lime is added to correct this condition, so detrimental to most crops. In fact, lime is generally added for this latter purpose, the physical benefits being to a large extent supplementary.

The action of the plow

Freezing and thawing, wetting and drying, organic matter and lime actually cause granules to form in the soil and induce crumb structure. Tillage implements, especially the plow, tend to accentuate this granulation and finish the work so well begun. We must remember the following maxim, however, regarding the plow, as it is a very important one. The plow is the best pulverizing agent known when the soil is in the right moisture condition. It is the very best of puddling agents when the soil is too wet. The soil should be of just the right moisture condition to receive the most benefit from plowing. If it is too dry it clods, if too wet it puddles. The optimum moisture for plowing is that which is best for plant growth. If the farmer can

gauge this accurately, he need never fear bad effects from the plowing of his soil.

The plow brings about its pulverizing action because of the shearing stresses brought to bear on the furrow slice as it is turned over. The soil is lifted, it is stretched, and it is twisted. That in contact with the moldboard is retarded by friction while the part above tends to slide over it, exerting an internal pulverization difficult to get by any other means. Lastly the furrow slice is thrown off the moldboard and shattered against that previously turned. When maximum pulverization is wished the moldboard is short and sharply twisted, thus intensifying the shearing stresses. Follow a plow at your next opportunity and study its action in light of the facts just presented. A few minutes will convince you that the plow is a wonderful tool and has a great deal to do with the preparation of a suitable seed bed. It should always be remembered, however, that the moisture content of the soil must be just right for the best results in plowing. Moreover, the "set" of the plow is an important factor not only for good work but for easy draft or pull. The setting of a plow is an art too often neglected.



FARMERETTE ON A MOTOR TRACTION DISC-HARROW

Power plowing and cultivating are making farming operations easier and more effective.

OPEN-PIT MINING WITH STEAM SHOVELS LOADING INTO WAITING CARS



Open-pit mining is a revelation to a visitor whose mental picture of a mine was the open shaft and tippie of underground mining. Three-fifths of all the ore used in the United States comes from Minnesota and the greater part of it is taken from open-pit mines.

THE STORY OF STEEL

(Copyrighted by the United States Steel Corporation)

The Material Which Makes the
Skeleton of this Workaday World

ONE OF AMERICA'S BASIC INDUSTRIES

I — The iron ore

ONE crisp, moonlight night, a stranger visiting the ore ranges of the Northwest stepped from a wood on the outskirts of a town in Minnesota and saw before him an immense hole in the earth, magnified by the moonlight—like the bed of a pumped-out sea. There was no sign of life, save a few scattered electric lights, and no sound but the puff of an engine far away at the bottom of the vast hole. The amazed stranger was told that this was a mine; that from this one great hole fifteen thousand tons of iron ore were being taken during the hours of that one night for shipment to the steel plants built near the great deposits of the coal required for the smelting.

This, then, was open-pit mining, a revelation to the visitor whose mental picture of a mine was the open shaft and tippie of underground mining. He stood on the edge of the hole and looked down at a great circular cut forty feet through sand and gravel; beyond that another cut, another and another—seven in all, projecting one beyond another like a succession of terraces, each wide enough for a line of railway, and each a deeper red in tone than the one above. And at the very bottom a great apron of red earth, honeycombed with trenches, like a battle front, with railroad tracks twisting in and out among the trenches, and a locomotive pulling a train of laden cars away from a steam shovel that was scooping out a bank of the red ore.

Three-fifths of all the ore used in the United States is mined in Minnesota; and the greater part of it is taken from open-pit mines such as this into which the visitor looked with astounded eyes. Some open-pit mines are like enormous stadiums, horse-shoe shaped, with different levels; some are nearly square; some are long and narrow—bent at one end into a curve, like a fishhook; some are simply long—a mile or two long, with surface earth dug out a hundred feet or more down to the apron of red ore. Before the steam shovel can bite into the ore itself, millions of cubic yards of surface earth must be removed.

Standing at the edge of the mine, the visitor looked down at a group of men on the terrace just below him. Some of them passed on down the slope with baskets strapped to their shoulders—carrying dynamite, he was told. A moment or two later, at a shriek of warning from the steam shovel, the miners bolted for shelter to the little steel safety tents scattered here and there along the terrace. All but one man—the foreman, who climbed on up the slope, stooping occasionally to inspect fuses and dynamite charges. Then he, too, retreated, lighting the fuses as he went, or pausing an instant to touch an electric switch. There was a still, tense moment; then, with a roar that reverberated over the countryside, a huge segment of earth split away from the hillside, leaped free and toppled to the ledge below, piling itself into a great heap of tree stumps, grass and earth.

INCLUDING MANUFACTURING, ENGINEERING, TRANSIT AND EXCAVATION

Immediately the steam shovel attacked the heap, grabbing out huge scoopfuls, and dropping them into waiting cars, which were dragged away by train loads as fast as they were filled, through the mine entrance, out upon a trestle or some hillside, where the train crews, standing on the "near side," yanked levers that tripped the cars and sent their contents sliding down the far side of the hill.

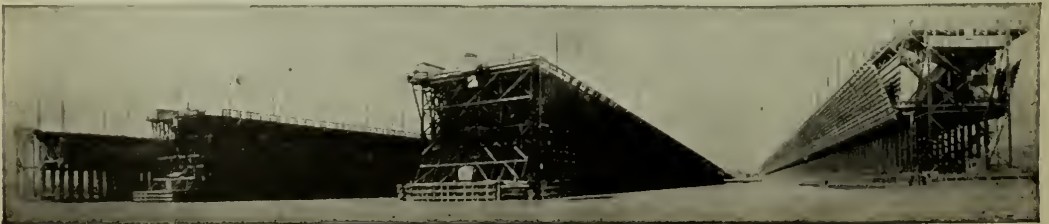
While the stripping was going on above, far down beneath on the great apron of ore were other steam shovels, tirelessly swinging their long necks. Near them was great activity. Locomotive whistles shrieked signals. Sappers moved ahead of the shovels, using powder and dynamite to loosen the densely packed ore. Section gangs of twenty men or more shifted the tracks over which the shovels moved as the work progressed, and railroad men brought up as they were needed the trains of ponderous empty cars.

This activity is continuous. Day and night the shovels burrow deeper into the rich ore that gives America its lead in the manufacture of steel. Day and night the huge jaws bite into the ore; the long neck swings from bank to car with its load, and back again — two tons or more at every bite, ten tons every minute — in five minutes filling a fifty-ton car. Not long ago a steam-shovel crew loaded 7689 tons in one shift, — the record, to date, in the loading of this ore. As fast as they are loaded, the cars are pulled out through the mine entrance to a railroad yard, where they are sampled and made up into train loads of fifty cars or more. Then a huge Mallet engine, with safety hand-rails and running board, is coupled on and hauls the cars over an automatic scale, which weighs and registers the weight of the load in each car while the train passes

over it at the rate of eight miles an hour, down the long grade, and away on the eighty-mile trip to the ore docks on the lakes. These docks are at Duluth and Two Harbors. They are complex affairs of three levels — first, the dock proper, jutting hundreds of feet into the lake; upon the dock, beside a basin wide enough to admit the great ore steamers, is a structure of heavy timbers, whose upper sections form pockets for the ore; and on the very top are lines of railway tracks.

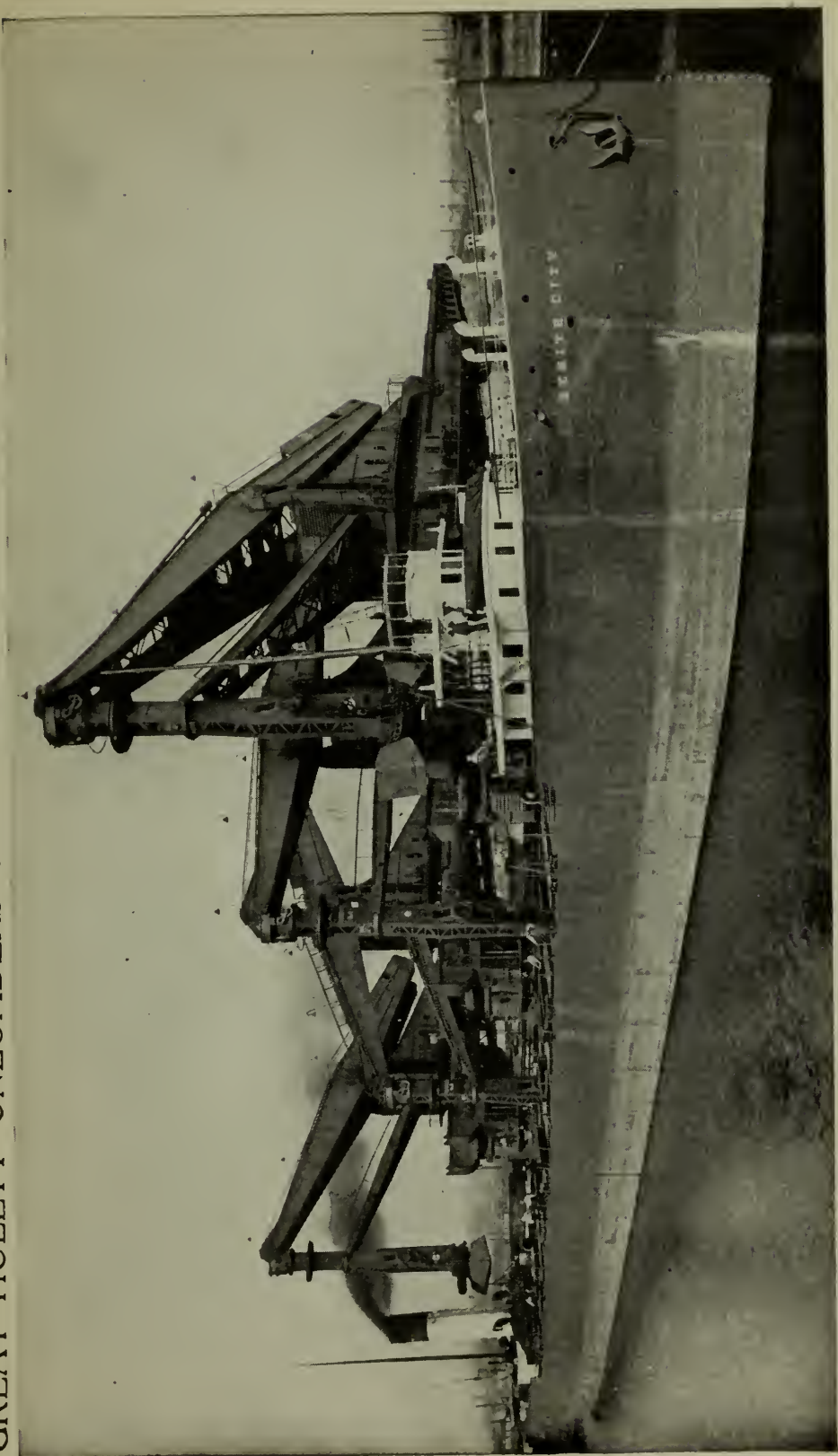
The loaded trains from the mines are run out upon these tracks over the ore pockets, and the contents of the cars is dumped automatically into the pockets. Then the empty cars are switched over to the return track and started back again to the mines.

One of the great fleet of ore boats comes up from a lower lake port, slips into the basin, and is made fast to the dock. This fresh-water ship, 600 feet long and only 60 feet wide, is an iron shell with houses at each end — officers' quarters and bridge in the bow, crew's quarters and engine-room in the stern. There are hatches spaced six feet apart all down the long open deck between the houses. As soon as the ship is made fast, these hatches are opened and from the ore pockets above are let down chutes which are folded flat against the pockets when not in use. The doors of the ore pockets are opened, two laborers with crowbars stand by to start the ore, which goes rushing down the chutes, through the hatches, into the hold of the ship — so swiftly that in twenty minutes a 10,000-ton ship is loaded; and a few minutes later, under its own steam, it puts out into the lake and joins the endless procession of boats carrying ore down to the furnaces all through the open months.



LAKESIDE VIEW OF DULUTH ORE DOCKS

GREAT HULETT UNLOADERS SNATCHING OUT FIFTEEN TONS AT A BITE



Courtesy Wellman-Seaver-Morgan Co.

FOUR 17-TON HULETT UNLOADERS AT WORK UNLOADING AN ORE VESSEL

An open bucket can be seen on the unloader at the right. The spread of the jaws is 21 feet. Each bucketful weighs 17 tons. The unloader descends into the hold of the ship, scoops up a bucketful, lifts it up and discharges it into a hopper.

Visitors are always impressed by the fact that most of the Minnesota ore is soft enough to go down a chute. It is soft like red earth, and crumbles like mold in the hands. Nowhere else in the world is iron mined so easily. Nowhere else is any commodity under the sun transported so cheaply. The English and the Spanish ores are harder and not so good. "Even if we have furnaces as large as yours," grumbled a German from Essen, "your machinery and skill and our organization, and coal as plentiful, *we haven't your ore!*"

Of course, not all the ore from the Missabe and Vermillion ranges and the other fields grouped about Lake Superior can be mined in the open-pit way. But even if the cost of mining by steam shovel exceeds the cost of underground operation, the steam-shovel method usually is preferred, because in open-pit mining fewer workmen are required, there are fewer accidents and the immediate output is greater. Also, since there are no heavy overhead charges or expenses for alterations and remodeling, the output can be increased when prices are high and lessened when prices are low, or the mine may be temporarily abandoned without great loss.

The chief objection to open-pit mining is the large initial capital required. The great steam shovels and the trains of cars that haul away and dump the stripping from the shovels are costly, and their upkeep and operation very expensive. There must also be great space for an open approach to the mine, as well as space for dumping the stripping. Nevertheless, open-pit mining is so generally preferred that, previous to 1915, on the Missabe range alone, more than 234,000,000 cubic yards of stripping — more than all the dirt removed in the digging of the Panama Canal — had been removed and carried off to dump heaps.

But not always does the visitor roaming the ore ranges come thus upon an open-pit mine. Often he finds the usual old-fashioned mine tipple, with ore cars rushing up and down; and sometimes he comes upon a scene of activity of which he must ask the reason. Inside an open pit, more than a mile square, imagine a group of

Alpine mountain climbers, all with ropes about their waists and picks in hand, stuck like flies on the side of a range of miniature red Alps. There is no mine tipple in sight — only these men on the red hill-sides of ore. "What are they doing?" the stranger asks. "Milling," he is told. Milling is another characteristic Minnesota method of getting the ore economically and safely. It is a simple way, and sometimes, particularly when space is limited, it is the most economical way.

In milling ore, instead of using steam shovels, or the old-style mine shaft with its dangers and limitations, the mining engineers, after prospecting to ascertain the value of the deposit, first have the stripping removed from a lay of ore. Then beneath it they drive a slope; and from the end of a great cellarway they drive other entries or tunnels. From these tunnels raises are made to the ore overhead; and then the Alpine mountain climbers, with picks and dynamite, loosen the ore above and start it pouring down through the raises to cars waiting in the tunnels below.

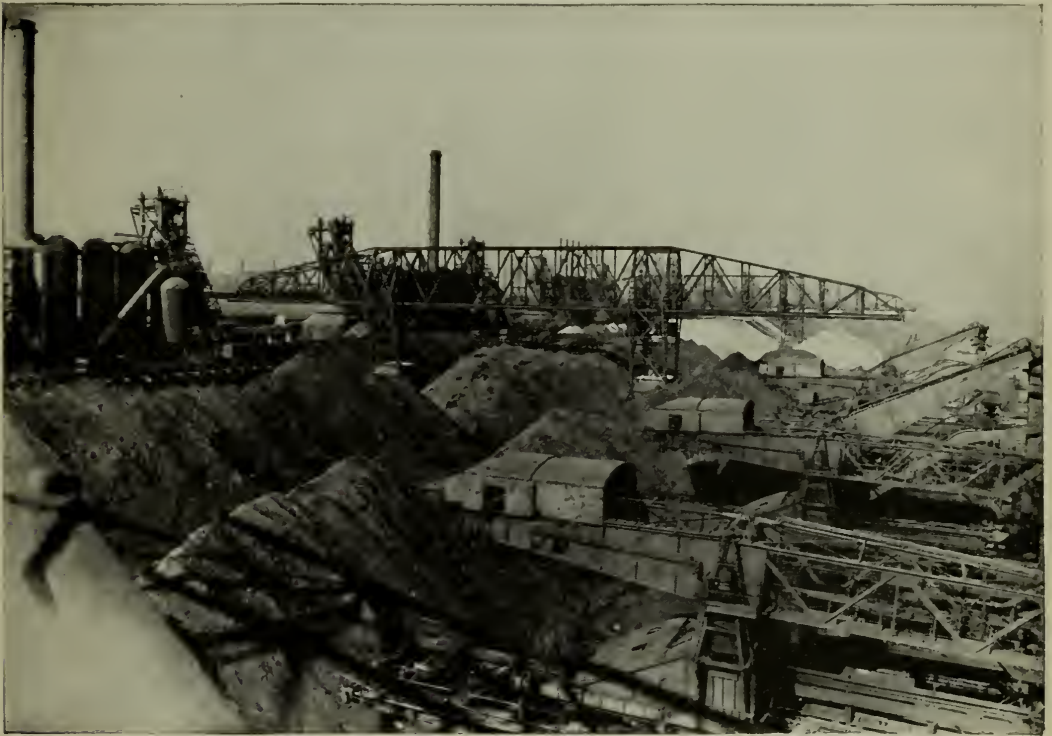
Which is best — milling, open-pit or underground method, seems to the person unfamiliar with mining to be a difficult question to decide in advance, since it would seem to him that practically all the elements of the situation must be guessed at. "If the mining engineer could know the exact location of each ore bed, and just how thick and deep it is and the quality of the ore," speculates the uninitiated, "then the problem would be a simple one." And this is exactly what the mining engineer does know before he finishes his exploration of an ore deposit.

Through the woods above a supposed lay of ore goes the engineer, carrying in his hand a dip needle so delicately magnetized that it dips instantly when over a deposit of ore. For days the engineer works along, making careful note of every needle reading and every outcrop of ore — "hard rock," the Indians used to call it when it protruded above the surface. In this way he determines the location of the bed; and the only problem left is to ascertain the depth and quality of the ore.

Formerly test pits were sunk to the ore bed, but drilling has now become the general practice. A drill crew is small and works swiftly. When a mining company desires to test a body of ore, it sets a dozen of these crews to work. Each packs its boiler and tools on a wagon and sets out often over ground so rough that they have to build a road. Arrived at the spot designated by the engineer in charge, the men clear a space and in short order the boiler is standing on end, a smoke-stack is stuck atop of it, and a small engine is

in the muck beside the sample barrels will have taken sixty or seventy samplings of the ore, which means that the drill has gone down 300 feet or more into the bed of ore and a sample taken every five feet.

The process of sampling the ore is interesting. The drill is threaded to the end of a hollow rod. As the drill works up and down, water is forced through the rod and comes washing through holes in the bit up inside the three-inch casing, bringing ore with it. These samples the man in the hip boots catches and throws into barrels.



UNLOADING THE ORE FROM THE STEAMER AT THE BLAST FURNACE

pumping a water supply through a pipe trailed off to some nearby stream. Soon a derrick is mounted and a winch put in place, and the men settle down to work. The engine, puffing like an automobile taking a hill, tosses white jets of steam over the tree tops, and the drill cuts steadily down through the earth. A driller hauls on the end of a rope that tightens about the winch. Up shoots the drill rod to the top of the derrick, and then plunges downward into the earth. At the end of a fortnight the man in hip boots standing

A churn drill, with a man half-way up the derrick to turn the drill as it works, is ordinarily used — always, if the ore deposit is soft enough. But sometimes it is impossible, even after the hard rock has been blasted away. Then they use a drill with black diamonds set in it, hard enough to cut through the most closely packed deposit. A core of the substance it is cutting through works up into the center of a hollow rod just above the joint of the drill. This core is pulled to the surface whenever a sample of the ore is desired.

These samples are then carefully dried, packed like coins into cloth bags, labeled and sent to the company's laboratories to be tested.

In this way the mine engineers in Minnesota determine the location of a bed of ore, and its depth and thickness and quality, and are able to tell the mine owners in advance practically all they need to know about the deposits beneath the surface. The selection of the method of mining is therefore less difficult than the uninitiated would suppose.

While the open-pit and milling methods are generally preferred because of their simplicity, safety and certainty of results, there are in all mine fields — even on the Missabe and Vermillion ranges — ore beds that lie so deep in the underworld that the sinking of test wells is impracticable. When the ore lies eight or nine hundred feet down, it becomes at once apparent not only that there is greater chance involved in going after it, but also that a method other than open-pit mining or milling must be employed. In such cases, the underground method must be employed if the ore is to be mined at all. This underground method is quite unlike open-pit mining or "milling." It resembles the method usually employed in coal mining, except that there is no "fire damp" or other explosive gas in underground ore mines; therefore, there is much less danger. Deep mining for iron ore will be made plain enough by reading our description of coal mining in another chapter.

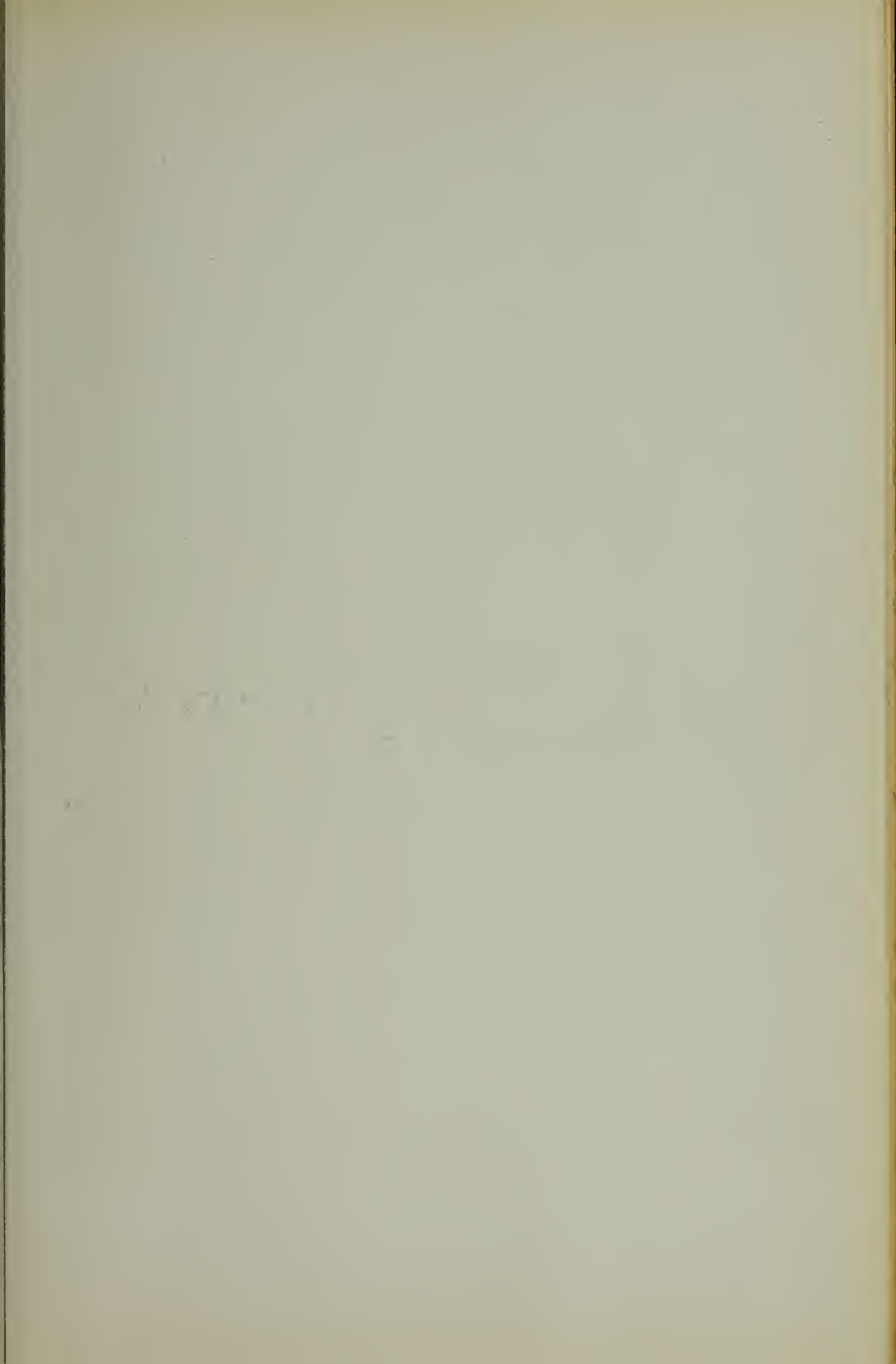
II—The coal and coke

Coke is the second ingredient in making iron, and it is, of course, obtained from coal.

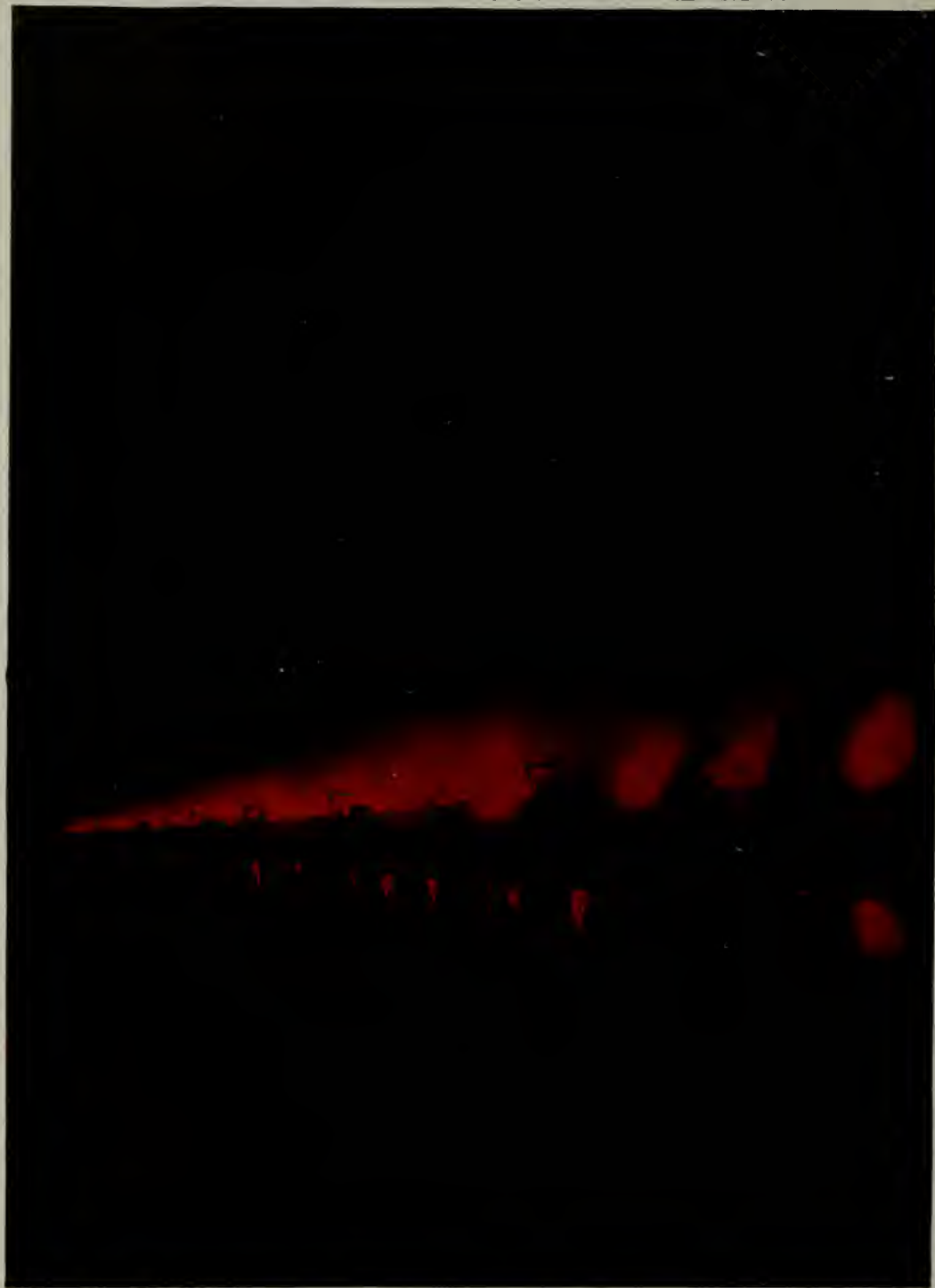
After the long arm of the cutting machine has bitten its way deep into the coal, and the charge of powder has loosened it, a loader gathers it back upon the waiting cars. Up the mine shaft the coal is sent to be tipped into bins or cars or larries — small cars, which, at some mines, are hauled off in little trains along the top of beehive coke ovens set close together, side by side. Nine hundred of them are operated in connection with one mine.

The coal is dumped from the larries through openings in the tops of the ovens. When the oven is full the contents are evened off by a leveler and the door is sealed up, except for an inch at the top. The whole operation of burning everything volatile out of the coal except the carbon is regulated by the amount of air entering this aperture. The charge is left in the ovens forty-eight hours, except at week ends, when, to avoid the necessity for Sunday work, it is left in seventy-two hours. This is reckoned from the time combustion is started by the heat retained in the fire bricks from the preceding charge. Finally, the door is removed, the long arm of the mechanical unloader reaches in and carries out the coke, and the larries fill the ovens with a fresh charge.

The coal in the Connellsville region in Pennsylvania yields about 62 per cent of coke; that is to say, 28 per cent of the coal goes up in smoke from the beehive ovens. That 28 per cent contains by-products worth almost as much as the coal itself. Such a loss was a serious one. It meant that in 1913 the beehive ovens in America sent up in smoke more than seventy-one million dollars' worth of by-products. To stop this waste, the by-product coke ovens have been developed. These new ovens save everything in the coal and increase the yield in coke from 10 to 15 per cent. They are like drawers, stood on their sides, and placed close together — long, high and narrow drawers. They are thirty-seven feet long, twelve feet high, seventeen inches wide at one end and twenty-one inches wide at the other — just wide enough for a great electric ram, mounted on a car that is driven along as needed to settle its force against the burning coke, when the door at the other end of a "drawer" has been plucked off and a quenching car is waiting in place to receive the flaming load. The ram thrusts itself forward and the great burden of coke, glowing red, falls in huge chunks out of the oven into the car. Then down the track the car goes clanging, under its own power, to disappear under the frame of a quenching station, where water is doused upon the

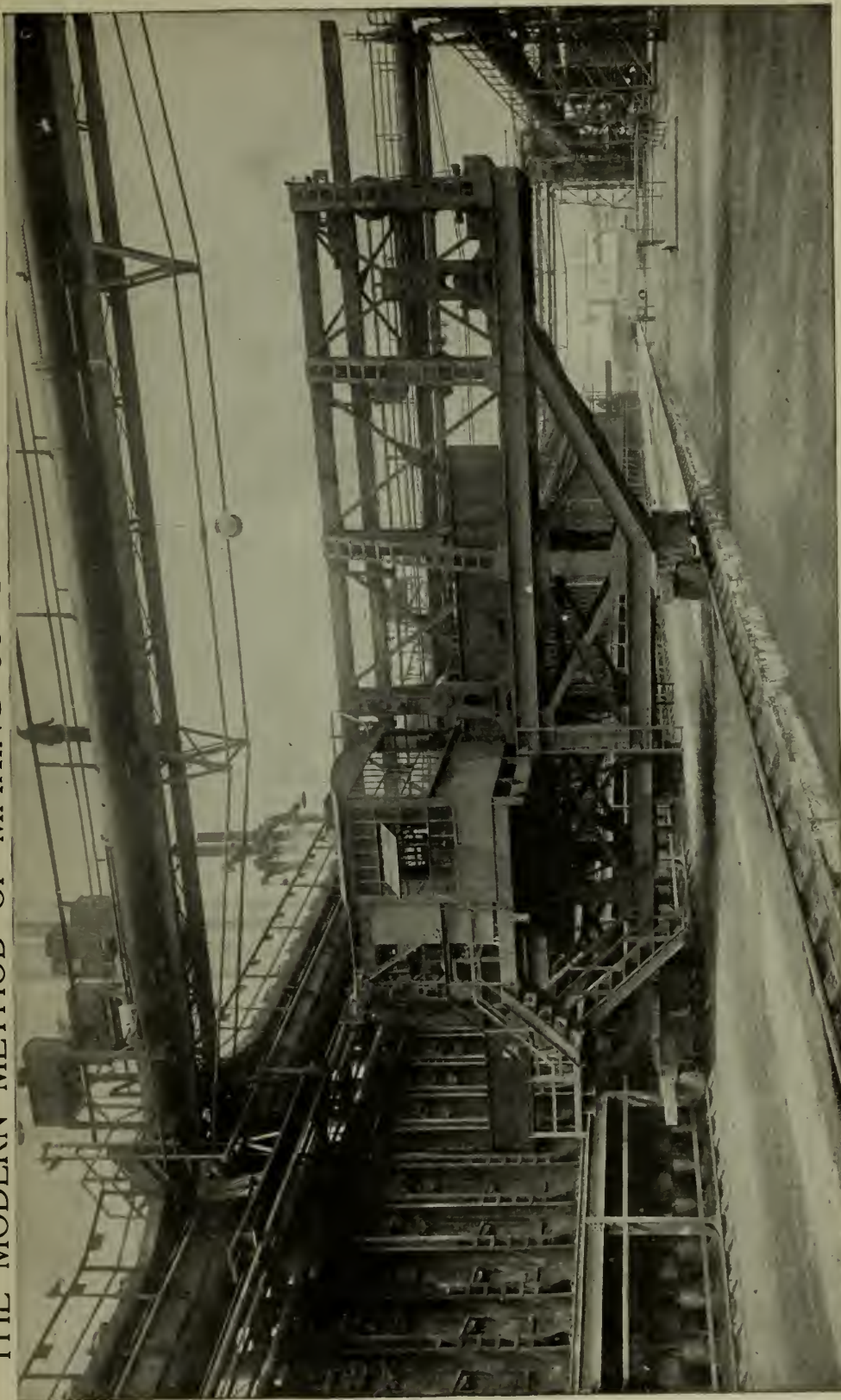


HOW THE COKE USED TO BE MADE



THE GLOW FROM THE BEEHIVE OVENS AT NIGHT

THE MODERN METHOD OF MAKING COKE AND SAVING BY-PRODUCTS



Courtesy H. Koppers Co.

BY-PRODUCT COKE PLANT OF MARYLAND STEEL COMPANY

This plant consists of 300 Koppers Ovens. The picture shows the coke side of batteries and the combined pusher, leveler and door machine, which removes and replaces coke-oven doors, pushes the coke from the ovens and levels the charge of coal in the ovens. At the left on top of the battery is the gas collecting main and overhead are the gas mains to the by-product building.

glowing coke. There is a loud hissing sound and steam pours in clouds through all the openings of the quenching station. The length of time water is poured upon the flaming load depends upon the moisture content desired for the coke — usually for blast-furnace requirements about two and one-half per cent. The operator can tell by the finely adjusted mechanism when the water should be cut off.

At the Gary plant of the United States Steel Corporation are 560 of these by-product ovens in two rows. Huge mains built along the tops catch the by-products that go up in smoke from the old-type ovens. About half of the gas saved is used to heat the ovens themselves, and the rest is used in the open-hearth and heating furnaces of the steel plant. Nor is this all. After each ton of coal has yielded its 75 per cent of coke and its ten thousand feet of gas, five gallons of tar and twenty to twenty-five pounds of ammonia sulphate, or five to six pounds of liquid ammonia, are saved. There also are extracted from the gas 1.1 to 3.7 gallons of benzol, a first cousin to gasoline, and a small quantity of toluol, chief ingredient of the strongest explosive known. In short, nothing is lost from the coal after it comes in cars from the mines, is dropped into bins and conveyed overhead to be pulverized and mixed and carried to the coke-oven bins above the larry tracks.

III — The Limestone

The ore is the first of the three ingredients used in making iron; coke is the second; limestone is the third.

Limestone — calcite is the kind desired — is quarried in a score of places in America. Shot loose with dynamite, it is picked up with steam shovels and carried in cars to a crushing plant. There crushing rolls, working like sledges, batter the rock as it is held against an anvil block. Lower and lower, steadily growing finer, it falls at last into bins. Then a chute and skip cars run it aloft again and revolving screens sort it into three sizes. That portion which is of the proper size is sent to the blast furnaces to be used as a flux in making pig iron. Limestone, after serving its

purpose in the blast furnaces, comes out with the other impurities in the form of slag — by-product, which is used in road building or made into Portland cement.

IV — Transportation

The place where the raw materials are brought together for the manufacture of iron and steel must be selected with due regard to the economies of manufacture and distribution. It should be near the ore or the coal (or both), or else be somewhere along the route of cheapest transportation, where the ore and coal may meet. Pittsburgh became the first great center of the steel industry, with vast fields of coal near at hand, a supply of natural gas originally plentiful, and excellent railroad facilities for the transportation of raw materials and the distribution of the finished products. Cleveland, half-way between ore and coal, and also the Mahoning and Shenango Valley districts, are centers of large activity in iron and steel. South Chicago is another great steel manufacturing point, close to the greatest railway center of the world, with Lake Michigan affording cheap and easy transportation of the ore and coal supplies in Illinois and Indiana. Gary is a few miles from South Chicago.

Into these centers the raw materials are poured — carloads of limestone, long trains of coal, and a constant stream of ore. One can *see* one train of fifty cars, each carrying 50 to 75 tons of ore, rushing downward from the mines to the ore docks on Lake Superior. One can *imagine* fifty or a hundred such trainloads. But even one hundred trainloads means only 350,000 tons; and the imagination refuses to picture the vast number of trains required to carry down to the docks the 60,000,000 tons produced by the mines about Lake Superior in 1916 — enough ore to fill a string of cars that would reach from New York to Honolulu. Sixty million tons of ore in 1916 — when in 1852 five barrels was the total shipment from the Minnesota ranges. August 17, 1855, was a banner ore day. On that day a vessel loaded with 132 tons of ore passed through the new Sault Ste. Marie canal from Lake Superior to Lake Michigan.

In September, 1915, an ore boat came into a dock at Duluth and took on 11,262 tons of ore in one hour. In one hour and forty-five minutes from the time of her arrival she started on her return trip down the lakes with her cargo of ore. In 1915, also, at one of the Lake Erie ports, the great Hulett unloaders, snatching fifteen tons at a bite, took out a cargo of 11,083 tons in three hours and forty minutes.

All the way from field to furnace, no human hand touches the ore; and no human hand touches it while it is fed to the blast furnaces, along with coal and limestone. Everywhere the machinery works with almost uncanny intelligence

formed. Even now, in almost as crude fashion the South Africans make steel. They fashion a plate of clay pierced with holes, and bake it hard. Then upon the plate they place ore and charcoal, kindle a charcoal fire underneath, and blow it with bellows till the ore melts and trickles down through the holes into a clay container, where fire is blown upon it till the smelting process is complete and it is ready to be hammered into rude tools and weapons.

On the same principle is the modern blast furnace—the monster that eats up two thousand tons of raw materials a day. All the iron that is used for steel



LOADING ORE INTO STEAMER AT DULUTH

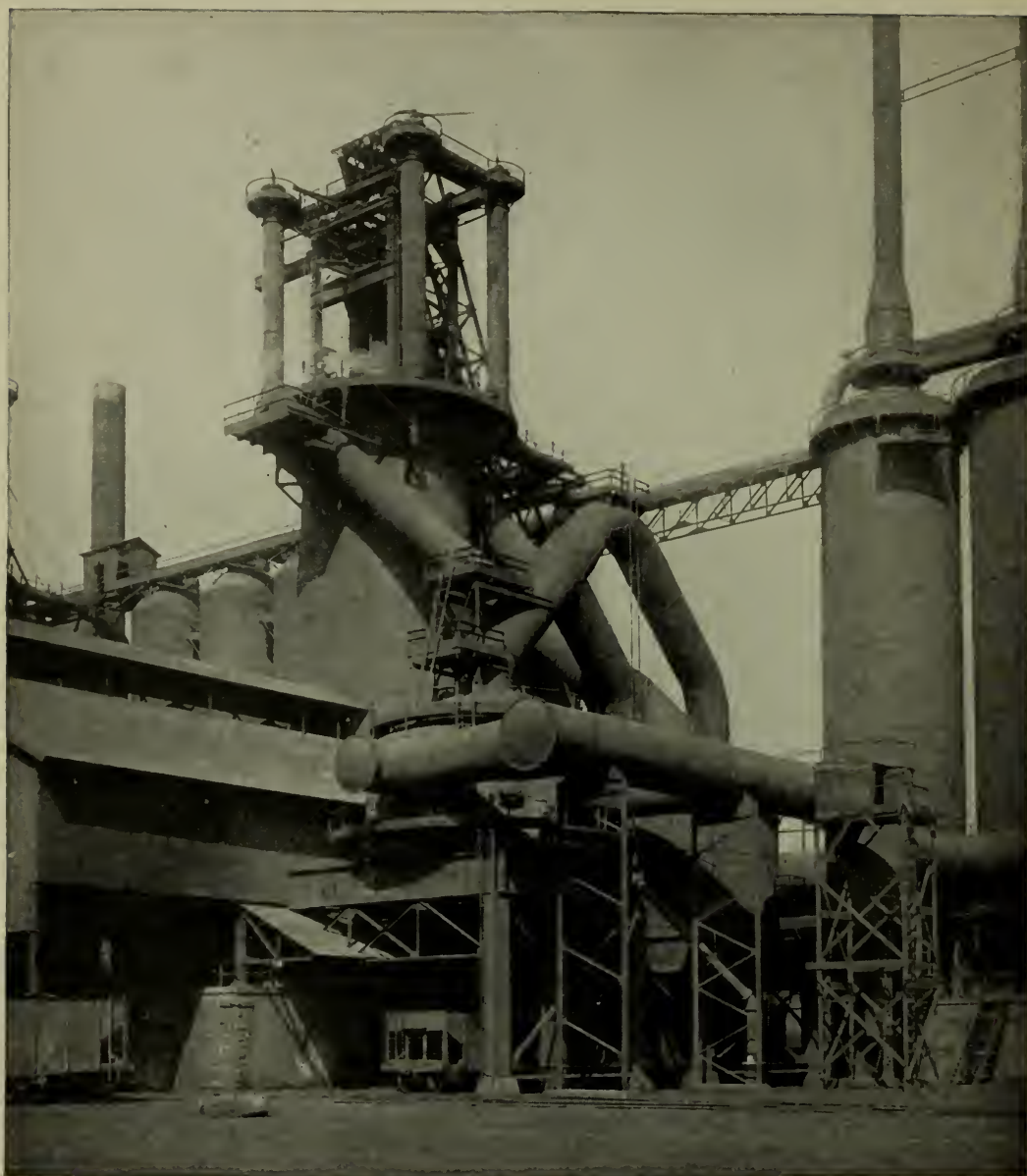
and precision. It all looks very simple, but by what perfection of detail has that simplicity been attained!

V — The blast furnace

Iron ore, as it is found in the ore beds, is composed of iron and oxygen with certain impurities. It is the purpose of the blast furnace to rob the ore of its oxygen, flux out the impurities, and leave the iron. The early makers of iron discovered, — doubtless by accident, — that if they sprinkled iron ore upon red-hot coals, raked other red-hot coals over the ore, then blew air upon the fire, the ore melted and a hard and durable substance was

has to pass through the blast furnace, where it is smelted with coke and limestone.

Most of the accidents that made the steel industry notorious in the early days occurred near the blast furnaces, but safety devices have so effectively chained these monsters that nowadays there are few accidents. The furnace cannot now spew its hot contents, even when a fresh charge of raw material is being crammed down its great throat, for a piece of hollow iron like a huge bell is lowered down its throat while its mouth is being filled, and a second bell is clapped over its mouth before the first one is loosened to allow the charge to drop down into the huge maw.



BIG BLAST FURNACE AT GARY

A blast furnace is operated continuously. Work may slow down, or cease, in other departments of a steel mill but the blast furnace keeps at its work day and night turning out pig-iron, so named because the molten metal used to be run out from the furnace into large trough-like molds called "sows," from which it trickled into smaller molds or "pigs," and was left to cool.

In the old days the molten metal occasionally ate through the shell of the furnace and dropped down to touch water and be hurled in every direction by the force of its self-generated steam. The modern blast furnace has a water-cooled shell, which reduces the danger of these break-outs; and at all points—especially at the top and bottom of the furnace—are

guards and safety devices that practically eliminate the possibility of accident.

A blast furnace is operated continuously. Work may slow down—may cease—in other departments of a steel mill; but day in and day out the blast furnace keeps at its work of turning out pig-iron, so named because the molten metal used to be run out from the furnace into large

trough-like molds called "sows," from which it trickled into smaller molds or "pigs," and was left to cool. Nowadays, unless used directly in the steel plant, the metal flows into molds fastened to an endless conveyor and run through water to cool it, or it is left to cool by natural process.

Huge stacks called "stoves" heat the air for the furnaces. They are a hundred feet high and something over twenty feet in diameter, lined throughout with brick. Gas from the blast furnace is burned in the combustion chambers of these stoves. The heated products of combustion pass through the checker work for an hour or more, heating the bricks to their full heat-absorbing capacity; then the gas is turned off, and air blast, supplied by the blowing engines of the furnace, is passed through these stoves in the opposite direction.

This air absorbs the heat from the bricks and then enters the blast furnace through pipes called "tuyeres" at a temperature of 1200 to 1400° F. In the furnace this heated air passes over the coke, burning it and creating an intense heat in the

hearth or bottom part of the furnace. The oxygen is taken from the ore, the carbonic acid from the limestone, the limestone and ore are fluxed, and the metallic iron trickles down into the hearth through the slag which is formed in this process.

Every four or five hours the tapping hole is opened and the liquid iron is tapped out of the hearth and run into huge ladles in which it is carried to the steel furnace, or cast in the pig machine.

It is hard to realize how much air a blast furnace consumes. Each of those at Gary consumes 37,500 feet of air a minute. Yet the air that is fed to a furnace must be carefully controlled — quite as carefully as the ore and coke and limestone — because a very slight thing will upset the digestive processes of a furnace. To illustrate, occasionally a small lump will fasten itself — "freeze" or harden — on the inside. The lump catches other particles, which adhere to it till a great mass is formed. The air coming from the stoves must then be heated to a very high temperature to assist the efforts made to melt out this semi-liquid mass.



THREE BLAST FURNACES AT CLEVELAND

Huge stacks called "stoves" heat the air for the furnaces. They are a hundred feet high and something over twenty feet in diameter, lined with brick throughout. Gas from the blast furnace is burned in the combustion chambers of these stoves.

The volume of gas from a blast furnace is tremendous. At Gary, 30 per cent of all the gas from the eight furnaces — a total of 22,450,000 cubic feet, the equivalent of 250,000 brake horse-power — goes to heat the thirty-two stoves. Some goes to the boilers; $12\frac{1}{2}$ per cent goes to the mammoth gas engines that operate the furnaces; and the remainder is used for various other purposes. None of it is wasted. In short, the gas from these eight furnaces, along with the surplus gas from the coke ovens after the by-products have been extracted, supplies the power for all the machinery and electric generators used in Gary's tremendous plants, which even supply the electricity to operate the unloaders on the docks. It also supplies all the power for two subsidiary plants, and helps to light the town. Some of it goes, also, to the open-hearth furnaces, where the smelted iron is turned to steel.

VI — The open-hearth furnace

At first sight an open-hearth furnace looks like a baker's oven. But when the visitor puts on a pair of colored spectacles such as the workmen use and peers through the water-cooled door, he finds himself looking across a great pool, thirty-five to forty feet long and fifteen feet wide, filled with bubbling white-hot metal, tinted here and there with delicate shades of pink and blue. It seems more like candy cooking than like steel, but during the ten to twelve hours of cooking in the intense heat of the gas the mass is converted into steel.

Metallurgists experimenting with iron ore long ago found that a mixture of raw iron, limestone and scrap iron heaped on a shallow hearth and heated to a high temperature by gas flames, would at the end of six hours be smelted into steel — very good steel, too. This open-hearth process is called an "open-hearth heat," and each time such a heat is tapped the world is richer by fifty to a hundred tons of steel.

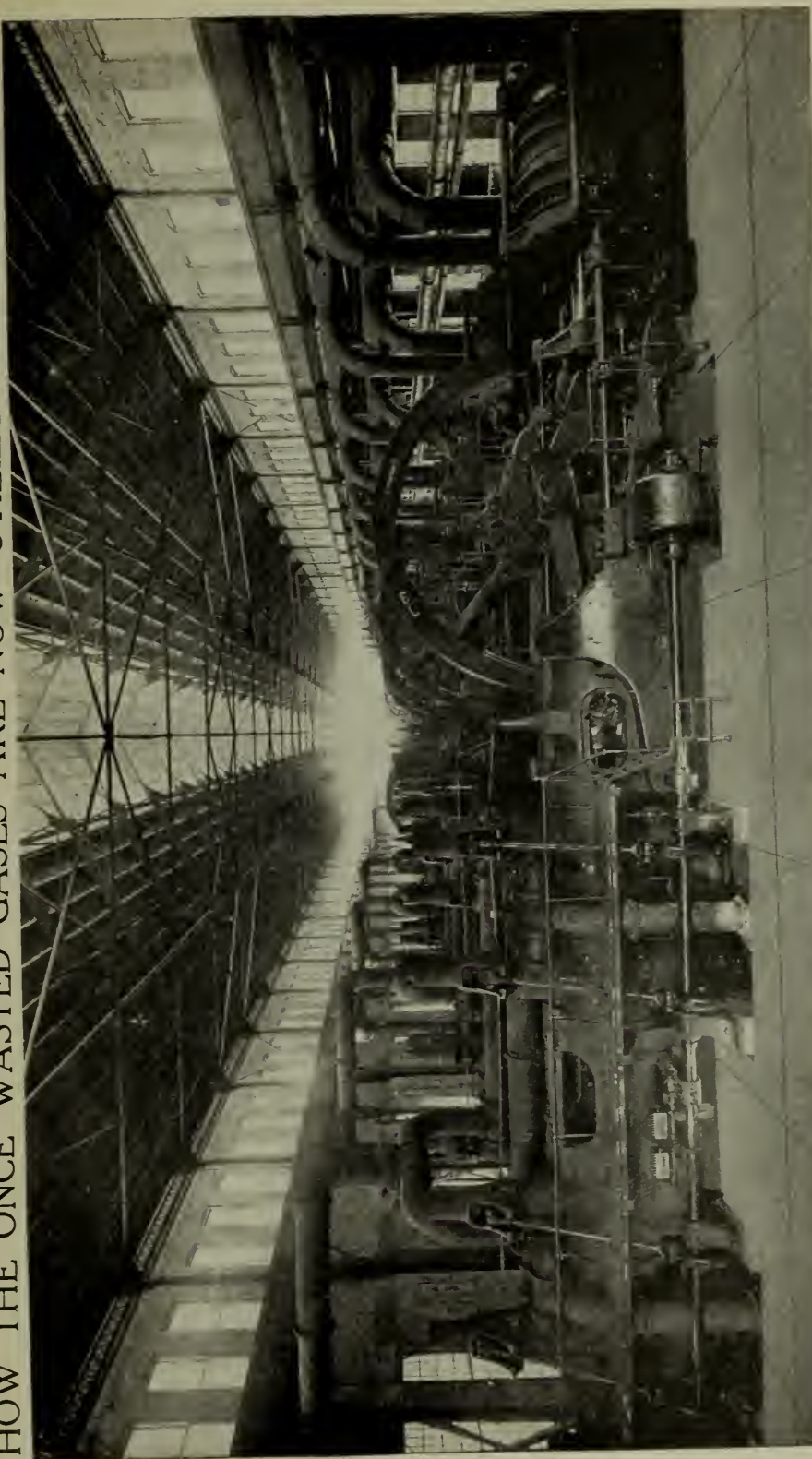
This explains why so little scrap iron is found lying about a plant. The scrap is used in the open-hearth process — not to get rid of it, but because it is needed. Before being sent to the furnace all the

large scrap is gathered into a space inclosed by heavy screening, where a huge ball is raised high by a powerful magnet, released and dropped down upon the pieces of old iron and steel, smashing them into convenient sizes for the furnaces. The broken scrap is then heaped on small cars with removable boxes and started for the open-hearth furnace. From another part of the plant yard, a trainload of ladles filled with molten iron is started toward the mixer — the gathering point for the hot metal as it comes from the blast furnaces. Into this receptacle, shaped like a huge teapot, the heats from the different furnaces are poured. Here they are equalized — made uniform in quality — before being poured out again through the giant spout into ladles and borne by cranes to the open-hearth furnaces.

Meanwhile, on the open-hearth floor, a supply of finely ground dolomite has been piled before the long line of furnace doors, and as soon as a heat has been discharged, laborers shovel in the dolomite, — which melts like glass and fills any holes that may have been burned through the lining, forming a solid bottom for the fresh charge. Then the charging begins. First, from the trainload of scrap which has been brought alongside the furnaces, an electric charging machine lifts box after box, pushing its burden through the door and tilting the contents into the furnace. Then an overhead crane brings from the mixer a huge ladle, swings it aloft, and pours the molten iron into the furnace. And from time to time during the charging a laborer throws in a shovelful of limestone. What one really sees bubbling on the surface of the furnace is the melting limestone gathering to itself the impurities of the steel and forming them into slag.

Steel, as one sees it in finished tools or rails, undergoes many changes between the ore and the finished product. The blast furnace smelts and refines the ore; but it is still iron as it comes from the blast furnace, with 4 per cent of carbon and $\frac{1}{2}$ to $1\frac{1}{2}$ per cent each of manganese and silicon. These ingredients, and certain amounts of sulphur and phosphorus, are

HOW THE ONCE WASTED GASES ARE NOW UTILIZED TO ADVANTAGE



Courtesy The Westinghouse Machine Co.

ONE OF THE GREAT POWER HOUSES OF THE UNITED STATES STEEL CORPORATION AT GARY, INDIANA

The combustible gases from the smelting furnaces are washed, purified and burned in these engines. The engines are shown on the left of the picture and the blowers that they drive on the right. The air from the latter blows the fires in the furnaces, which, in turn, furnish the fuel for the engines.

considered impurities, though carbon in limited quantities gives hardness, and manganese toughness to steel. The percentage of impurities can be well regulated in an open-hearth heat. It cannot be regulated as fully in the Bessemer process. It is regulated in both cases at the end of the heat by adding the necessary amount of carbon, manganese, etc., either in the molten or solid state. This explains the additions of *spiegel*, ferro-manganese, ferro-silicon, etc.

In the Acid Bessemer and Open-Hearth processes it is not possible to remove the objectionable element, phosphorus. It is therefore necessary to use ores very low in phosphorus to make pig-iron for these two processes. In the Basic Bessemer and Open-Hearth, phosphorus can be removed at will and reduced to whatever amount is required for making the various kinds of steel.

To watch the tapping of an open-hearth "heat" is an interesting experience. At the rear of the furnace is a great open space. Overhead is an electric crane, equipped with an extra steel-and-asbestos shelter having an extra power controller, for the crane-man's use in case of accident, for all these operations are most carefully safeguarded. At the side farthest from the rear of the furnace is a pouring platform, upon which the molten metal is poured into molds from ladles carried to the platform by the overhead crane.

One of these great ladles is brought to the rear of the furnace when a charge is ready for tapping. While it waits for its load a gas flame is kept burning inside it, to dry out every trace of moisture. More than once a few drops of water under molten steel have caused a fatal explosion. When the time comes for tapping, a workman, quick and sure as a cat, poises himself in a niche provided for the purpose and jams a steel bar through a clay-plugged hole at the base of the furnace. Out tumbles the steel into the waiting ladle. Scattering a trail of many colored sparks and glowing like a stream of gold, it lights up the whole mill. Higher and higher it mounts, till the ladle is full and the slag, loaded with impurities, overflows and

congeals on the outside. Then the crane-man lowers his chains, and, catching the ladle by the lugs, swings it over the pouring platform, where other men tap it and pour the contents into ingot molds mounted upon cars.

VII—The Bessemer converter

But by far the most interesting thing in steel making is the Bessemer process. Imagine a huge arena like the Roman Coliseum in one corner of which is a raised platform, where stand several men operating hydraulic levers. A little lower, to the left, is another platform, and alongside this, a third. On both these lower platforms men are pouring steel into ingot molds mounted on cars which are hauled away as fast as they are filled. Looking down the arena from a niche beside the highest platform, the spectator sees three enormous, egg-shaped monsters, hung on a level with the platform but at the other end of the arena. Then a whistle shrieks. "No. 3 is going to pour," says the guide; and one of the monsters—a huge egg with the top sliced off—tips itself over on its trunnions and pours into a ladle its twelve-ton load of steel that glows like the sunset and shoots millions of sparks up against the metal roof, through the dim traceries of girders, and all down the length of the vast place. Quickly a man on the platform pushes one of the hydraulic levers, and up turns the huge converter, end on end, while from its glowing mouth tons of slag pour into other ladles. Back half-way to upright the vessel turns. Out over the bridge beside it a man picks his way carefully, his eyes shielded by colored glasses, and peers at the red and white bottom that is to hold more molten metal. Sometimes he finds that the bottom is satisfactory. When it is not, he hurls balls of clay at holes in the bottom where the fire brick is eaten away, or sets a crew to work putting a new bottom on the half-cooled egg or patching a hole in its interior. If all is right, he merely gives a signal and makes his way back over the bridge, while a car is run out with ladles full of blast-furnace iron for the next charging. Its contents

THE OPEN-HEARTH FURNACE



CHARGING HOT METAL



TAPPING A HEAT

Each time a heat like this is tapped the world is richer by fifty to one hundred tons of steel.

are poured into the great paunch of the converter, and air is sent coursing through one of the trunnions, down through an air box at the base of the converter and up again through holes. There is a mighty roar. Up toward the ceiling showers of sparks are sprayed, their color changing constantly as the carbon and silicon in the iron is burned.

Day and night, except on Sundays, the work in the Bessemer mill goes on, the shifts being changed three times daily; and the glow from the molten metal rises high over the mills.

VIII — The electric furnace

Very different from the Bessemer is the squat little electric furnace that makes the best steel of all, because it can be controlled so accurately. The high-grade alloy steels — vanadium, chrome-nickel and manganese steel — come from this little fifteen-ton furnace, which usually has half of a great building to itself, while in the other half other furnaces are busy preparing the metal to feed it. A crane pours the metal into the furnace. Gas is not used for heating; an electric arc does the work instead. This arc is struck between the metallic charge and large electrodes capable of conducting tremendous currents, which are passed through the top of the furnace down to the surface of the slag. The electric circuit of which they are a part is completed through the metallic charge in the furnace, so that an arc is formed at the point of contact of the electrodes with the slag. "The rest is not difficult," says the furnace manager. "By varying the materials used in the formation of the slag, that is, simply by using different kinds of flux, all the steel's impurities can be coaxed out to join hands with their chemical affinities. Alloys can be added at pleasure. And when the metal is ready the crane spots a ladle in place for it and then carries the ladle off to a pouring platform, where it is poured into ingot molds just like other steel."

All the processes of steel making converge in the production of the ingot. The ingot is to steel what bar gold is to currency. It is the common denominator

— the standard by which the production of steel is measured. And when the molten metal has been poured into ingot molds, the intrinsic business of making steel is ended. Thereafter it is only a matter of fashioning from the ingots the shapes desired.

It would be practically impossible to list the things that are shaped from ingots — all the millions of articles required in trade and manufacture and building in this age of steel. There is space here to describe only a few of the processes that shape the ingots into the forms most convenient for use.

IX — Rolling mills

As soon as the ingots are stripped of their molds, they are drawn off to the soaking pits. Here the long and strong arm of a crane reaches down its tong-like fingers, plucks them one by one from the cars, and sets them down into small pits heated by burning gas, where the ingots that are to be rolled remain for an hour and a half — the time varies for different kinds of steel. In these pits the ingots are said to "set." This means that they become of like texture throughout, so that there is no soft core at the center. When the operator finds that the ingots have set, he raises the temperature in the soaking pit very carefully until the steel is of just the right texture for rolling.

Out of the pit, then, the crane's tong-like fingers pluck the ingot and set it on the rolling table, poised ready to dart between two great revolving rolls, each a yard in diameter and ten feet wide. The ingot braces itself, trembles like a live thing, then darts away down the table. There is a crash, and the sizzling of cold water on hot surfaces as it strikes the aperture between the rolls and wriggles through, assisted in its tortuous course by the revolving wheels beneath it, and its movements guided and controlled by levers operated from a sort of pulpit on the nearby wall.

Clearing the passage between the rolls, like a huge, red, live thing, the ingot is flopped over upon the table, by hand-like manipulators, operated by levers from

THE BESSEMER AND ELECTRIC PROCESSES



25-TON BESSEMER CONVERTER — BLOWING A HEAT



ELECTRIC FURNACES — CHARGING HOT METAL

a safe distance. It reverses, raises itself, and comes smashing back again to take a fresh start on a different level and dash down again between other rolls, growing thinner each time. So, nine times in all, it performs, at the will of the lever operator in the pulpit, until it is only a quarter of its original thickness and very long. Then down the broad runway, over the rolls, it is sent to the blooming shears, which snip off its rough edges, slash it in twain and send the pieces on to the first of the roughing rolls, where again each part braces itself, wriggles between the rolls and comes out on the other side with its first semblance to an ordinary steel rail. Three times each part is passed through the first roughing rolls, on to second roughing rolls for a single pass, to dummy rolls for another, and at last to the finishing rolls, where, in four passes, each part is given its final shape and comes out a long rail, writhing like a snake along the runways a quarter of a mile from its original starting place. When it comes to rest, three circular saws cut it into sections. And there are the finished rails, ready to be cooled and straightened, loaded into cars and sent out to be spiked down to some distant fairway of traffic.

X — The finishing mills

In practically the same way are formed billets, which are really small ingots made into smaller sizes for a hundred manufacturing purposes. These billets are heated again and rolled into bars, then drawn through dies into wire — wire that is chopped into little pieces that the machines batter and point into nails; wire that is woven into fence; barbed wire; and unbelievable quantities of telegraph and telephone wire.

Fabricated steel, for bridges and buildings, is also shaped by the rolls. I-beams, channels, angles, are rolled and sent along to the fabricating shops to be put together as parts for bridges, for giant skyscrapers, for the construction of subways, and for the holds of ships. In the bridge shops these parts are swung about by mighty cranes, punched by hydraulic punches cutting through a dozen places at one

bite; reamed ready for hot rivets, riveted together and finally made ready to set up as a bridge over some distant stream — perhaps high in the Andes, or in China or Japan.

Having followed the billet from the rolls to the finishing mills, one may go back to the rolls and see slabs being made. The slab is another crude form, smaller than the ingot, rolled flat, of any thickness desired. From it plates are rolled. From the cars in which the slabs come from the rolls they are tossed to smaller cars and run down a trackway to a crane — the most human crane ever devised. From time to time it wets its fingers in a nearby pool of water to cool them when they get too hot from picking up the slabs and setting them into the heating furnaces. It dances along before the furnaces as if it delighted in its work. Indeed, so human are its motions, the workmen sometimes say, in reporting an accident, that "the charger has broken his nose." The red-hot slab is plucked out of the furnace, dropped on a cart, and snatched away to the plate mill, which is simply a different kind of rolling mill. Here it is passed back and forth between rolls until it is as long as each sheet to be made from it must be wide. Then it is rolled into a piece that may be from a quarter of an inch to one and one-half inches thick, and run between other rolls, where it is straightened. The plate is yanked by men with long tongs on to a bed of "goosenecks," looking like bed castors stuck in the ends of short pipes with one end embedded in the floor. The long piece of flexible steel slides over these "goosenecks," on through cold straightening rolls, and along a cooling frame; thence it works gradually down a long course like a bowling alley, to a room where great shears snip off the rough edges of the plate and slice it into the size required. At last an overhead crane drops down a huge magnet, grips many of the sheets together, and swings them over to cars alongside, ready for shipment. Slabs are sent, also, to jobbing mills and tin-plate mills, where they are treated somewhat differently. The jobbing mills roll

THE MAKING OF INGOTS



POURING A HEAT



STRIPPING A HEAT

The molten metal is poured into ingot molds which are then stripped off while it is still white-hot.

sheets between an eighth and a sixteenth of an inch thick only. The tin-plate mills roll sheets all the way from a sixteenth to an eightieth of an inch — sheets so thin one can almost see through them. To the furnaces of these mills the slabs come in thickness according to the sheets to be rolled, and are heated. In a long, wonderful building, with plenty of light, a great flywheel spins softly. On each side of the flywheel, working on the same shaft, are four roughers and finishers — eight mills to a drive, for each of these machines is called a “mill.” They are interesting — these mills — like huge wringers and mangles, with water-cooled rollers spinning round and round in them. Each mill is operated by two men, a “rougher” and a “catcher.” Over and under the rolls, the roughers and catchers flit glowing pieces of steel back and forth, through the roughing mill, through the finishing mill, the sheets all the while growing thinner, till in the jobbing mill the red sheets are matched together and played through the rolls two at a time and in the sheet mill six to eight at a time.

The sheets are snatched away at last, in a pack, over to the side of the room, where the shears trim off the rough edges, and workmen with tongs pull the sheets apart, and heap them on little cars, which carry them on into another room. There a hood, shaped like an ancient sarcophagus, is dropped over a pile of sheets. This hood is then sealed with clay, placed in an oven, and subjected to intense heat till the sheets are cherry red, to anneal, or temper them.

Some of the sheets are galvanized, which means simply that they are first dipped in sulphuric acid, then doused into water to wash away the acid, and afterward run, one at a time in a long row, over the end of a tank where they are dipped in muriatic acid, then through a tank filled with molten zinc, where they receive a coating which, on cooling, gives the little frosty spangles that characterize galvanized steel; then they are run on to a cooling rack.

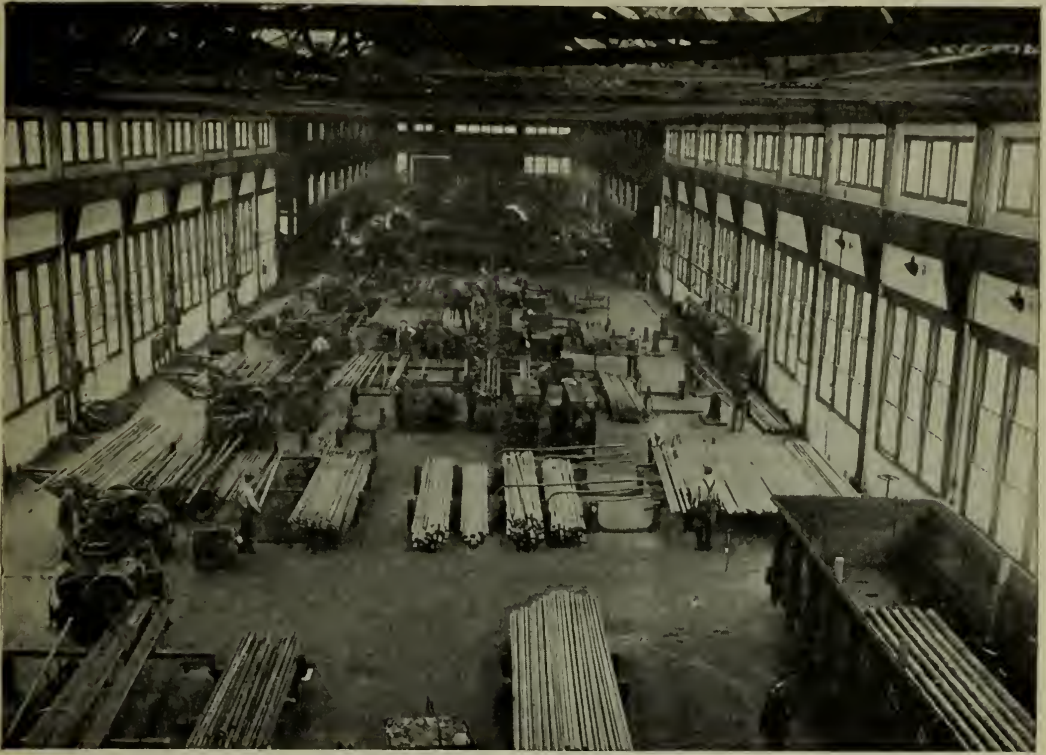
Other sheets are coated with tin. They come bright and clean from the zinc baths, and are dropped into a porcupine rack.

This rack receives the sheets between its quills, letting them cool while it rolls slowly over, and drops them on the packing platforms. Thus, in one plant may be seen sheet tin being packed and sent out by the carload; in another, sheet steel — “beautiful, blue stuff” the steel men call it — is being shipped away to be made into a hundred different things — automobile bodies, filing cases, the hulls of ships.

Billets are used also in the making of pipe. In a huge saw-tooth building one may see the pipe made — miles and miles of it, for all sorts of uses — fifty miles to every building of eight or nine stories, fifty miles to every great ocean steamer, a hundred miles to a structure like the Woolworth Building.

The billets are brought in by the carload. The cranes dance them into the furnaces and later flick them out on the rolls, which flatten them till they are the exact thickness desired for the pipe that is to be made from them. Then a long rod grips them and pulls them through a die which gives them a cylindrical shape. This is the process for pipe from two to eight inches thick. If the pipe is to be larger, the flattened billets are passed sidewise through rolls so that one end may overlap the other. From the rolls the long ramrod carries the pieces back through the furnace, whence they come at welding heat and are sent between two rolls over a ball — a round piece of steel of exactly the diameter of the inside of the pipe — which rests inside at the end of the long steel ramrod. Then, after straightening and testing, the pipe is ready for shipment. This process is called “lap-welding.” Seamless pipe is made by distending a steel plate between dies, or by piercing a steel billet through the center and rolling it over a mandril. In the process of butt-welding the rolled-out billet from the furnace is drawn through a bell that curls it up and welds the edges together by pressing one against the other. Butt-welded pipe is not as strong as the seamless or lap-welded, but it is sufficiently strong for all uses where the steam or other pressure is not heavy and the heat not intense.

TUBE AND WIRE MILLS



THREADING FLOOR OF NATIONAL TUBE MILL



GALVANIZING DEPARTMENT OF THE DONORA WIRE WORKS

One may walk miles through the vast building — over safety platforms above danger spots; along paths between huge piles of pipe of a hundred kinds; past men fitting threads to the ends of steel pipes as large as thirteen-inch guns; past lines of red-hot pipe ricocheting and rattling safely down upon cooling tables; under great cranes that shriek their warnings while swinging their burdens from place to place in the mill or out upon flat cars for shipment.

And throughout this vast realm — in the mines and mills, the furnaces and the finishing shops — every precaution is taken to safeguard the men who are performing the difficult and dangerous labor of making steel, to prevent accident, to instil caution, to impress upon the workmen their responsibilities toward one another, to the end that this great work may go on with due regard to the preservation of human life.

In the mining towns and the mills the welfare and comfort of the workmen are carefully looked after. In the mines they no longer work in dark holes in the ground, wet and filled with noxious gases. Every mechanical appliance is employed to make the work easy and effective and to preserve the health and comfort of the men while at work.

In every mining center effort is made to provide for the miner during his shift above ground reasonable opportunities for recreation and enjoyment. In the mining and mill towns are social centers, with club facilities, where the men may enjoy games or read in the library. For their children there are schools and playgrounds. Visiting nurses look after the sick in their homes. Men who are injured in the work are cared for in the company's hospitals.

The United States Steel Corporation provides in many of its mill towns comfortable houses, equipped with appliances for heating and lighting, with water supplied through the company's mains, and proper arrangements for sewage and garbage disposal. The men are proud of their houses and their gardens, and there is great rivalry among the gardeners.

Many of the mills have provided restaurants where the workmen can eat good food at reasonable prices in clean, comfortable surroundings; and when the whistle blows, the workmen can go to sanitary wash-rooms where they may take a shower-bath and change into their street clothes, which have been hanging up in private lockers, and go out into the streets of the town, clean and refreshed.

Under the employees' stock subscription plan the workmen are encouraged to become shareholders in the corporation. Stock is offered to them slightly below the market price, to be paid for by deductions from their salaries. They have three years in which to pay for each subscription for stock, but from the time the first payment is made on the subscription, the dividends are credited to the subscriber; and the corporation also pays a bonus of \$5.00 a year on each share of stock.

When a man has served his term of usefulness and has come to the time for rest, the corporation pays him a pension sufficient to insure comfort and freedom from anxiety as to his support during the declining years of his life.

The matter of the safety and welfare of the workmen is as much a part of mining and steel making as the direct processes of the industry themselves.

The processes described in the foregoing pages are common, with slight variation, to the many iron and steel manufacturers who have made the United States the leader in this branch of industry. Her output of iron in 1920 was nearly 37 million tons, and of steel over 42 million, being more than twice as much as Great Britain, France and Germany together. Canada, that produces over a million tons of pig-iron annually, is building a large iron and steel plant at Ojibway, near Windsor, opposite Detroit. It has been laid out on the lines of Gary and will have approximately the same tonnage capacity in certain lines. Niagara Falls will furnish light and power, the water of the Detroit River, on which the town and plant are situated, flowing 250 miles further to develop power that is transmitted back by wire.

ROLLING AND FINISHING MILL

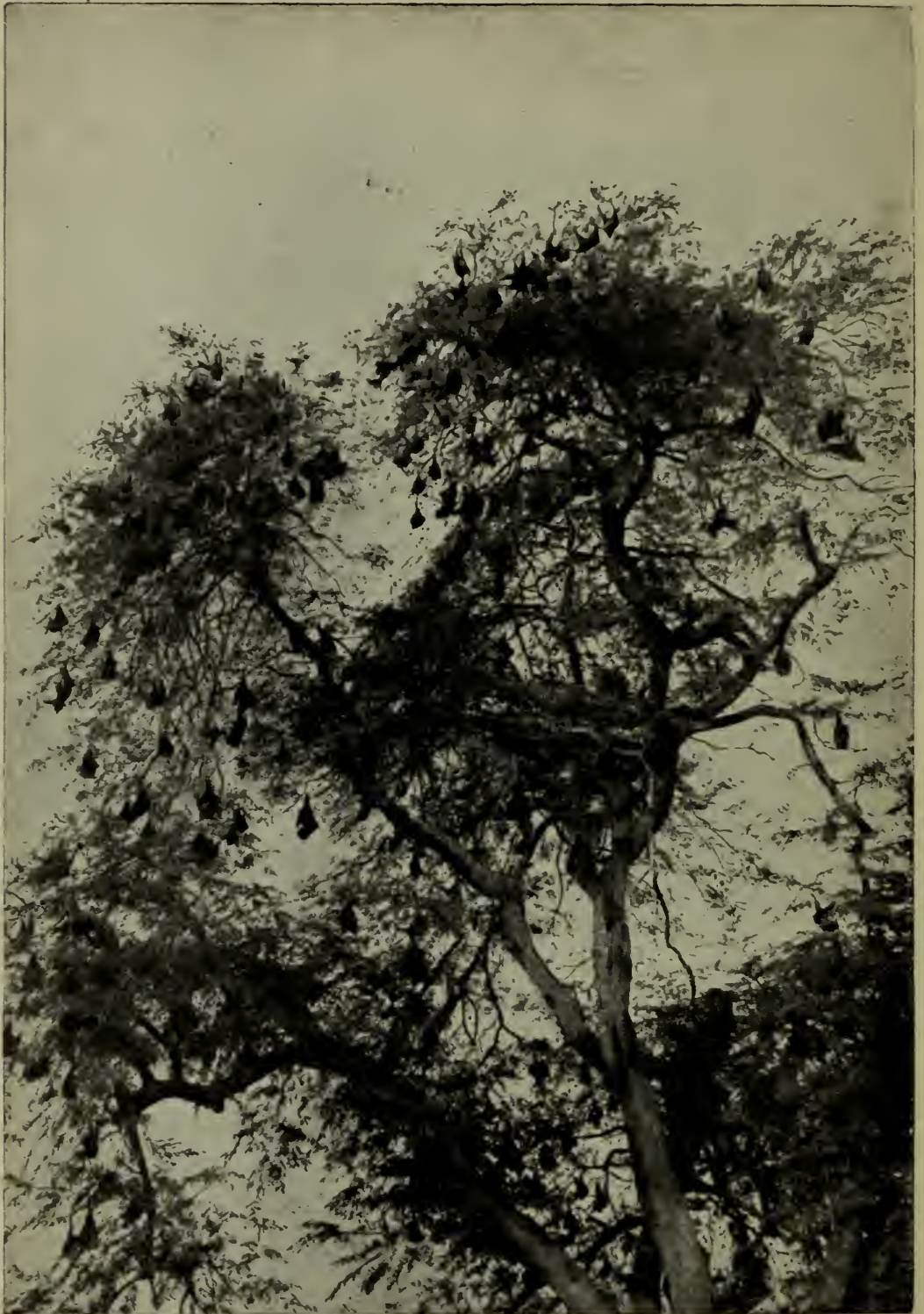


CONTINUOUS ROD MILL



RAIL FINISHING MILL

A SWARM OF FLYING FOXES FAST ASLEEP



A swarm of flying foxes — the fruit-bats with the long, fox-like faces — may often be seen hanging asleep on a tree in India, and at close of day a long procession of them wings its way to pillage the fruit-trees.

EVOLUTION BEFORE OUR EYES

The Way in Which Life in the Animal Kingdom
Today Helps to Explain the Changes in the Past

LIVING CREATURES ON THE BORDER LINE

THE naturalist is a highly scientific detective. The mystery which he essays to unravel is the story of animate development, a profound and fascinating scheme. He must be able not only to detect the difference between a deer and an antelope, but to recognize at once the characteristics which separate both from other families; and must be able, further, to trace the features by which all animals are related in the scheme of life. The casual observer would set down the newt and salamander as reptiles, and the whale as a fish, though the merest tyro in zoölogy knows that the first two are amphibia and the third a mammal.

Not from motives of pedantry are the distinctions made; the distinctions are priceless guides to the scheme of things that the naturalist has to study. He must know things as they are individually, how they are related one to another, how they came to the form and characteristics by which we know them. External evidences are not enough for him. The zoölogist must have the aid of the comparative anatomist to tell him how animals, greatly differing in appearance, agree well enough in vital structural detail to be classed in the same order. To trace the story of the development of a species our detective must have the assistance of the embryologist, for the magic of past history is revealed in the prenatal stages as by no other method known to science.

Lastly, there is the testimony of the rocks, brought to light by the paleontologist, the student of the fossil remains of what, millions of years ago, were animals. These tell us what the ancestors of existing

types were like. There we see how new species, diverging from the original stock, grew up; and the embryo of existing representatives makes plain to us much of the detail of the story. The naturalist works on from clue to clue until finally he is able to present the whole enthralling romance of the pageant of life. Casting round, in the light of knowledge gleaned by way of these channels, he is able to trace the age-old progress of development to its newest chapter, now unfolding before our eyes. He can trace life down many a blind alley, flash a light upon creatures which have missed their way, so to speak, or have specialized too much and become freaks.

Some of these creatures remain, as mile-stones, marking the way along which the great currents of life have surged. Little columns of limestone mark the measured mile in the Clyde over which battleships and ocean liners run their trials. These mile-posts are the fossilized remains of billions of living creatures of the sea. Changed to stone, they serve to point the course of mechanical monsters of newer deeps. And some such purpose in nature is served by groups of curious creatures at which we may now glance. Scientific classification is, of course, disregarded here; the animals chosen are those which may be considered, in some sort, steps — though not, of course, successive steps — in the scheme of living things.

We may begin with the tunicate and the lamprey. Here are two of nature's children which have obstinately refused, or neglected, to grow up. The lamprey is not a fish, though it lives in sea and river.

It has neither fins, nor scales, nor jaws, though its sucker-mouth and tongue have teeth. It set out to be a vertebrate — a backboned animal — and the primal impulse still animates the embryo and the free-swimming young. But the promised backbone never fully arrives, and the lamprey, like the hideous hagfish, remains lower than the true fishes, if higher than the worms.

The tunicate is a still more glaring instance of good intentions unrealized. The adult is invested in a sort of tunic, from which it takes its name. The young tunicate starts life fairly well, with a notochord and a supporting rod in the tail. Now, the notochord is simply a fibro-cellular cord or rod found in the embryo of all backboned creatures from man to mouse, and it is replaced in the perfect form by the spinal column. Equipped with this physical good intention, the young tunicate begins its career a free-swimming, active little animal, alert and industrious as a tadpole, with every prospect of attaining to the dignity of a backbone.

The little Micawber for whom nothing ever turns up

The tunicate proves, however, to be a Micawber for whom "something" never turns up. It eats and swims and busies itself with futile assiduity. Inherited inertia supervenes; the nervous system degenerates; the tail is absorbed, the eye disappears, the notochord breaks its promise, or proves barren; and the creature, in its adult form, anchors itself at a convenient place, and throws about itself a cloak whose texture resembles the cellulose of which the walls of plant cells are composed. The promise of the higher life is forgotten, and a hopeless animal of the lowest type, comprizing both sexes within one frame, remains as a finger-post to the past days when nature was evolving her types.

We find greater wonders in another order low on the ladder of life — in the jellyfishes. Here, in the medusæ, for example, we have a creature compounded almost entirely of sea-water, but so combined as almost to pass man's comprehen-

sion. This mass of water, confined in a sort of web, makes up an animal with appetite and passions, with power to inflict injury, to capture and consume its prey. It is equipped with that gift of light which enables it to turn the seas on summer nights apparently to liquid silver.

The creature chiefly made of water, with children unlike itself

This jellyfish gives birth to young entirely unlike itself. The young retain their first form throughout life, but give birth to offspring with the form of their grandparents. From the jellyfish proceeds young in no way resembling itself, and from these issue jellyfish. And this creature about whose life-story these wonders congregate, is chiefly sea-water. From a specimen weighing 4 or 5 pounds there remains, after evaporation, only a film of solid weighing as many grains.

An audience, before whom a learned professor was lecturing on this subject, contained a thoughtful farmer whose land lay upon the coast. "Is it true," he privately asked the lecturer at the close, "that these jellyfish are chiefly water? I have been employing men and horses to cart tons of them from the coast as manure for my farm." He was not consoled when assured that in a ton-weight of newly gathered medusæ there would remain but four pounds of solid matter after the water had evaporated.

The electric fishes which light up the seas with unmatched splendor

Some steps higher in the scale we meet a function more surprising than the stinging power of the jellyfish — the genuine electric discharge of the electric fishes, the electric eel, the cat-fish, and the electric ray, or torpedo. The early creatures of the sea probably knew all about the hurtful qualities of the stinging power of the jellyfish; and it was probably very early in the story of civilization that man discovered that, though a healthy discharge from an electric eel sufficed to stun him, the same discharge, carefully used, possessed curative properties for certain human ailments.

These fishes were the earliest electric machines used by man. The light-giving jellyfish, emits a phosphorescent fluid from its tentacles; the electric fish has its batteries in modified muscles. The great armored fishes are dead and ended, but the electric fish, with its smooth and slimy coat, flourishes in salt water and fresh, and the jellyfish, synonym for all that is impotent and futile, still peoples the seas in unthinkable millions, and illumines it with unmatched splendor.

We trace a distinct advance toward the higher life when we reach the lung fishes. These, restricted to Australia, to West and Tropical Africa, and to the Amazon region in South America, have been forced to use the swim-bladder as a lung. It did not take the fish out of the water, or at any rate it did not take out all that developed in this direction. For we have the true lung fish today, as we have had it ever since Permian times. The device serves

to be held in remembrance, as, with his rival, he suggests the means by which the first amphibians survived, when low tide first left them, high and horrified, upon dry land.

to be held in remembrance, as, with his rival, he suggests the means by which the first amphibians survived, when low tide first left them, high and horrified, upon dry land.

It is specially interesting that we should have these two fishes, as well as representatives of primitive amphibians and reptiles, still with us. The amphibians, the animals born in water which come ashore to live, are among the most detested of living creatures, yet they are among the most interesting. Here we have the descendants of the first backboned animals with hands and feet, fingers and toes. From such creatures as these grew the gigantic dinosaurs and the monsters

of the marshes and the waters of the early world.

Truly the history of the ages is marvelously told in the natural history of the frog or the toad. From the tiny egg emerges the little sable streak of life with wide-spreading gills fanning in the waters, and the tiny tadpole swims with absurd activity about its petty business with the very action of an industrious



A FLYING OPOSSUM

The wing, or flight membrane, of this little Australian "sugar squirrel" is broad, extending from the outermost toe of the forefoot to the ankle of the hind foot.



AN ANIMAL WHOSE HABITS HAVE CHANGED ITS STRUCTURE

The great anteater of South America, a living relative of the giant sloth, is a remarkable example of adaptation to circumstances. Living on ants, this comparatively huge animal has lost all traces of teeth, and has the tiniest hole for a mouth at the end of its elongated skull.

travel, but this is by means of an adaptive trick enabling him to keep his gills well moistened while he scuffles along on his

minnow. Only the practised eye can tell the young tadpole of a frog from the toad or the newt, so closely does each resemble the

THE STRANGE ANIMALS THAT SEE THE



THE COLLARED FRUIT-BAT NESTLING ITS YOUNG AS IT HANGS FROM THE BOUGH OF A TREE
The bat spends most of its life, when not flying, hanging by its thumb from a tree. Of all the many ways in which animals have sought escape from their enemies, that of the bat is, perhaps, the most remarkable, for the bats, alone among mammals, have converted their hands into wings, and, without feathers, mastered true flight. They were insectivores, of which moles and hedgehogs are typical examples today.

WORLD AS THEY HANG UPSIDE DOWN



THE TWO-TOED SLOTHS OF SOUTH AMERICA, WHICH ROLL UP LIKE A BALL AS THEY HANG FROM A TREE

The sloths, when moving or feeding, hang, back downwards, suspended by their hook-like feet and hands. These uncouth creatures move from bough to bough in a lazy, cautious manner, and when sleeping they roll themselves up into a ball resembling the lichen-clad knots of the trees they inhabit. Like the bats, who also see the world mostly as they hang upside down, the sloths are animals of the night.

other. As the tadpole grows, as his little hind legs appear and his forelegs follow, as his gills disappear, and finally the real frog's jaws take the place of the lamprey-like mouth, we see clearly how nature has worked her way through the scale of progress to give us this curious two-legged, two-handed amphibian.

And we wonder, in the spring, what courting-time must have been like in the days before man. The toad so placid and retiring in the warm days of summer, is in springtime the very embodiment of

lovmaking the primeval marshes must have resounded! The newt, the salamander, the frog, and the toad remain to remind us by their life stories of the prehistoric sea monsters which were among those first able to live on shore. A still more notable signature by the hand of Time is written for us, however, in the anatomy of the sphenodon of New Zealand, a reptile neither lizard, nor crocodile, nor tortoise, but having links with each. Its head suggests both tortoise and crocodile; so do certain of its ribs. In



A PAIR OF EUROPEAN NEWTS AT HOME—THE MALE AND FEMALE OF THE CRESTED NEWT

Living in water during the breeding season, newts, as a rule, pass the rest of the summer on land, seeking shelter beneath stones and roots, or in holes, in which they pass the winter asleep. The crested newt, which is larger than the American, feeds largely on tadpoles.

ardor and activity. He is a changed beast under the influence of the reproductive instinct. His voice is terrific, his throat is enlarged, and its coloring altered, so that whereas ordinarily it differs but slightly from the tint of the rest of the under side of the body, now it is livid. The timid beast has suddenly become invincibly bold; he swims with amusing vivacity, restless, consumed with passion; night and day he is at boiling-point. If the old-time giants of the class to which he belongs were proportionately ardent when they wooed, with what cyclonic

other respects it is clearly an anticipation of the earliest birds, and of the lowest of the mammals. One of the earliest of reptiles, it has lagged in a backwater of life through unnumbered æons, while from the family of which it is the sole survivor there emerged many important orders totally unlike the original-type.

The sphenodon is our oldest "living fossil," preserving for us characteristics which have remained through millions of years unchanged. Not the least interesting of its features is the pineal eye, which in this reptile is more clearly seen than in

any other existing animal. Every vertebrate has the remnant of this third eye, but until an examination of the organ in the sphenodon made its purpose clear, this unused organ of vision was regarded by followers of Descartes as the "seat of the soul." We owe the true explanation to the sphenodon. We call that useless eye which lies buried deep in the brain of the sphenodon a rudimentary eye. It is nothing of the sort. It is a remnant of an eye which once served some purpose.

But the interesting features of this animal are not limited to its teeth. Its whole life story is enthralling as casting a light upon the past of the mammalian class. The female lays eggs from which the young are hatched, blind, naked, and helpless, round-mouthed, ready to suck the milk ejected from the mother's glands. The secretion of the milk is effected from glands lying at the base of a little cup-like depression. The platypus is fur-clad like a mole, and has webbed, clawed feet suit-



THE DUCK-BILLED PLATYPUS AT HOME. A MAMMAL WHOSE YOUNG ARE BORN FROM EGGS

The duck-billed platypus and its cousin, the echidna, both natives of Australia, are unique as the only mammals whose young are born from eggs. This curious creature lives in burrows with a tunnel leading into water, where it swims easily with the aid of its webbed feet. The picture shows male and female.

The duckbill and the spiny anteater are as precious relics among mammals as the sphenodon is among reptiles. They are the most primitive of mammals, but the changes they undergo in development are sovereign testimony to the fact that they do not represent the original form of the first mammal. They are descendants of animals which had five pairs of teeth in each jaw. The young platypus still has teeth, but these wear down and finally go altogether, and in their place grow up horny ridges, so that the beak of the adult is a very good copy of that of the duck.

able to its life in the water and to its burrowing habits on land, where it makes its nest. It has many points of resemblance to extinct reptiles, and the temperature of its blood is lower than in most mammals.

The spiny anteater, or echidna, has a very bird-like mouth, but it has a long, rasping, cylindrical tongue, as have all anteaters, of which the echidna is one. It lays a single egg, and places it in its marsupial pouch, in which its young, when hatched, is suckled.

Here, in these two animals, we have suggestions of the step by which nature

proceeded from the reptile to the mammal, from the cold-blooded to the warm, from the young hatched from the egg and left to take care of itself from birth, to the young dependent from birth for sustenance upon its mother. But whether we may safely regard the marsupial pouch as a rudiment or a remnant, there is reason to doubt. Nearly all the animals of Australasia — the home of the egg-laying mammals — are marsupial. With the exception of the duckbill and the echidna, they produce their young alive. That may be, perhaps, overstating the case. The young at birth are hopelessly immature, mere embryos, and have to complete their development in the external pouch, attached to the teats by which they are automatically fed without any voluntary act on the part of the young. It was formerly believed that marsupials constituted the ancestral type of mammals, but later investigations encourage the belief that the marsupial is, after all, a degenerate type — that it at one time gave birth to young as well developed as the young of the rest of the mammalia. The naturalist-detective is not able to

predict discoveries with the same confidence as the astronomer, but he is looking with high hope to the day when the secrets of certain strata in Africa shall be laid bare. There, perhaps, the history of the mystery will be revealed.

Diet is at times a fairly good guide to the nature and order of an animal, but it is far from being infallible. Seeing that the echidna and the South American anteaters depend almost entirely upon the same form of food,

there might be a disposition to group them as belonging to the same order. As a matter of fact, however, the comparative anatomist compels us to recognize that that freakish animal with the huge claws and the long snout, the great anteater, has the sloths as his nearest allies. To the same order belong the pangolins and the armadilloes, though some authorities demur to this classification. Differing widely as they do, they are thus grouped because of the remarkable character of their teeth. The distinction is not

an enviable one; the members of the order have either no teeth at all, or teeth of rather degenerate structure, lacking both roots and enamel, and none have the front teeth.



A RARE TYPE OF ANIMAL ONCE SPREAD OVER THE WORLD
The chevrotains, or mouse-deer, are the sole survivors of animals once widely spread over the Old World. This African species readily dives and swims.



THE ZEBRA ANTELOPE OF LIBERIA

A rare denizen of Equatorial West Africa, the zebra antelope, sometimes called the "banded drinker," is distinguished by its striking color, its ground color being golden brown, broken by eight or nine black stripes.

Vastly as they differ in form and habit, the members of this group can be traced back, through various fossil forms, to a common ancestry—a striking example of the divergent courses taken by the branches springing from a common stem. There have been monsters in their house, the giant sloth most remarkable of all, but they are a degenerate family. The sloths are driven to the trees, the foliage of which they eat, surveying life as they hang from a branch, barely able to make their way along the ground when necessity compels them to quit the trees, to which they attach themselves by hook-like claws. It is not a little remarkable that while the tunicate puts on a cloak of a sort of vegetable fabric, so the sloth, hanging gloomily in the trees, develops a vegetable growth upon his hair. A minute alga grows luxuriantly in the cracks or flutings of the coarse outer hair, so that the slug-gard of the mammalian class appears to be part of the tree in which he passes his melancholy existence.

The result is a masterpiece of protective coloration, for the sloth assumes a greenish tint exactly matching the foliage upon which he subsists. But it is the expedient of inertia; nature appears not to be proud of the edentata. They are a dying order. Most of the branches of the family are extinct.

For the rest, while the sloths take to the trees, other members of the order have

been compelled to put on armor, to burrow underground, to move stealthily by night; while one, the two-clawed anteater, emulates the sloth in hanging back-downwards from the branches of trees in which it makes its home. Degenerate though they be, these animals are vastly interesting. Anything more grotesque or extraordinary than the great anteater, living only in South America, with its tube-like mouth, its immense bushy tail and its huge claws, could not well be con-

ceived, though its distant cousin of the Old World—the aardvark, or Cape anteater—with its thin, pig-like snout, its worm-like tongue, its uncouthly fashioned body, equally deserves a place in the long list of nature's freaks.

In a genus of a higher order we have one of the old-time puzzles—the tapirs. They are to be found (1) in the Malay Peninsula, Sumatra, and Java; and (2) in Central and South America—in these

places, and nowhere else. This curious distribution seemed substantial evidence in favor of the theory of distinct creations for these very widely separated localities. But the naturalist-detective has shown that, though wide seas roll between the homes of the existing types, tapirs were once among the most widely distributed of hoofed mammals. They flourished in England, they inhabited the Arctic Circle, thus proving that the climate of the far north was once genial, with abundant vegetation. The ancient land connections



AN UNGAINLY BEAST OF SOUTH AFRICA

Found in South Africa, north of the Orange River, this ungainly and melancholy looking antelope, the brindled gnu, or blue wildebeest, has quite a comic appearance when indulging in its characteristic caperings.

by which these animals traveled have broken down, shutting them in where we find them. Climate changes, variation of food supply, and other causes have sufficed to effect the obliteration of the species which remained in that part of America where the tapir is now unknown. 'Many changes in animal structure have come about since the tapir assumed its present form, but links have been found associating it with the rest of the hoofed mammal family, and one of its ancestors, the palæotherium — extinct wild beast — tapir-like in general outline, possessed features which foreshadowed the horse tribe.

How nature arms her offspring for the fray as exemplified in the musk-ox

The change from warm climate to cold suffices to account for the disappearance of the tapir from the north, but a reversal of the process robbed large territories of another beast as strange, the musk-ox. Here is the connecting link between the sheep and cattle, but nearer acquaintance with the takin, which in turn links the goats and antelopes, induces the belief that it is to this long-sought animal that the musk-ox has closest affinity. Be that as it may, the musk-ox is one of the most interesting examples of the way in which nature arms her offspring for their battles with special conditions. She hates waste places, and sends to one the musk-ox, marvelously resembling the sheep in certain particulars, highly specialized for its life upon slippery, ice-covered ground by the presence of gripping-hairs between the hoofs; a cud-chewer, and yet displaying affinities to the non-ruminant. Only in the wildest, dreariest parts of the arctic regions is this strange compound of designs now to be found, yet the superficial deposits southward reveal the remains of the musk-ox of our cold and distant past.

If diversity of design distinguishes the musk-ox, confusion of parts is still more pronounced in the gnu. It is an antelope, and has limbs proper to an antelope. But it has the mane and tail of a horse, the horns of an ox — in structure, though not in outline — and in general anatomical

features it resembles the African buffalo. The make-up of this strange creature might suggest that nature, trying a variety of structural schemes in as many different animals, decided to see how they blended in one and the same creature. She endowed the gnu with qualities as conflicting as its physical features. Thus, while timorous in the extreme, these creatures are the victims of consuming curiosity; and though they flee like the wind at the first sight of danger, curiosity draws them back, and fright and inquisitiveness conflict while the gnu capers and leaps in the vicinity of the hunter until the fatal bullet puts an end to curiosity.

A tiny deer, without horns, spare of build, which is still true to type

After these examples of extreme development, of the curious results to which evolution leads, we may turn for a moment to the other end of the scale, to view not, indeed, originals, but as near to originals as we can get, in the chevrotains, the pretty little animals which preserve for us the earliest picture of the deer family. They have been traced back to ancestry from which all the deer tribe sprang. Whereas the rest of the family have developed in shape and size, adapting themselves to varied climates and conditions — from the far-northern habitat of the moose to the peaceful scenes of the park deer — the little chevrotain remains true to type, an animal without horns, spare of build, little more than a foot high at the shoulder, progressing over the ground on tip-toe with a stiff-jointed gait, placed lowest in the scale of family honors, yet most highly to be revered as the most ancient type of deer. In human society the oldest families are the aristocracy, but with the aristocracy of the animal world the newest are the aristocrats; the most highly developed type heads the family tree.

Nevertheless, though no one would spare the lordly moose, the most magnificent development of the deer tribe, none of us would sacrifice the little chevrotain, reminder of the humble days when all deer were tiny and little specialized.

The story of evolution as told by the antlers of the deer

There is a very interesting chapter in evolution to be read in this contrast between the chevrotain and the elk; and the student may extend it by examination of the antlers in successive years of a growing deer. There we see at once the story of the animal's growth from year to year, but when we know a little more we realize that in the development of antlers year by year, from small and simple to large and branching, there we see also the reproduction of the story of the deer's development from age to age. Each year's condition of the antlers represents an epoch in the history of the deer family.



JAVAN CHEVROTAIN

The small antlers developed in the deer's first year stand for the class of antlers carried by the most primitive deer when they had first begun to develop these weapons. The antlers drop off, and are succeeded in the following year by antlers which begin to branch, so marking a corresponding development in the past history of the family. And so the story runs, from one geological period to another, the history of successive epochs retold by each year's development of antlers. But the little chevrotain remains to tell us of the early era when deer had not put on antlers at all.

Certain reptilian characters remain in all birds, but there is no survivor of the leathery-winged, featherless creatures of bygone ages which had teeth and talons to aid them in the battle of life.

An attempt to reconstruct a chapter of evolution

No bird survives today to show us what was the character of the first of these forms to develop wings and mount into the air. We have, however, a number of so-called flying animals to teach us how reptiles and mammals first began to fly; and the bats, one of the most remarkable and ancient of surviving mammalian orders, flourish in mighty hosts to elaborate the story. The insects, perhaps, were the first things to fly, and their flight would impel their pursuers to emulate them. The earliest animals contented themselves, no doubt, by pursuit on foot, in and out of the herbage, into the soil, up and down

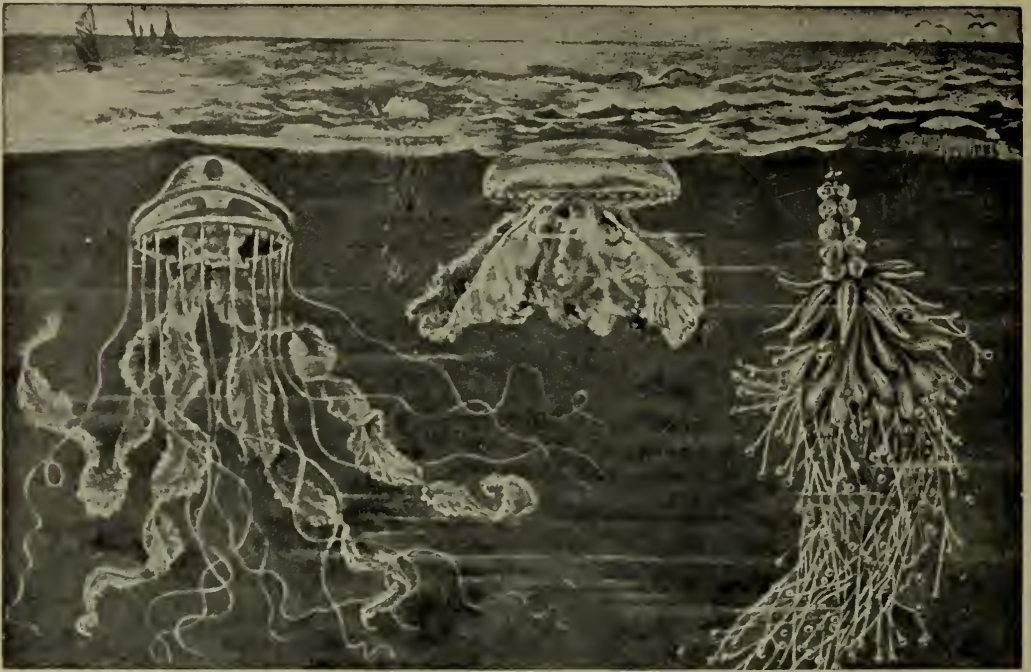


INDIAN CHEVROTAIN

trees. But presently some of them risked the first attempt at flight by launching themselves into the air and breaking their fall by outspread limbs and distended skin.

Nature is a complaisant parent, permitting her children to try all manner of experiments, and rewarding intelligent effort. The first result, or the best result, short of true flight, is to be found in the flying lemur, an animal which, without wings, can cover a distance of 120 feet at one swoop.

This wonderful flight is accomplished by a singular modification of the animal's skin, which, beginning at the throat, provides a collapsible parachute, extending from both sides of the body out to the extremity of all four limbs — short of the



JELLY-FISH—THE MARVELOUS CREATURES LOW DOWN IN THE LADDER OF LIFE WHICH ARE MAINLY

claws — and stretching from the hind legs to the tail. The claws serve for climbing; the parachute enables the lemur to plane from a great height in a downward and forward direction, and even after a dip, to soar upwards, carried by the original impetus. With slight modifications, the same arrangement of the skin serves the flying phalanger of New Guinea and Australia, the flying mouse, or opossum, of the same continent, the flying squirrels of America, the flying frog, and the flying

lizard. The so-called "flying fish" manage their flights of 500 feet at a time, and more, by means of strikingly developed pectoral fins, which they utilize as a parachute. The flying gurnard compasses his excursions above sea-level by much the same means.

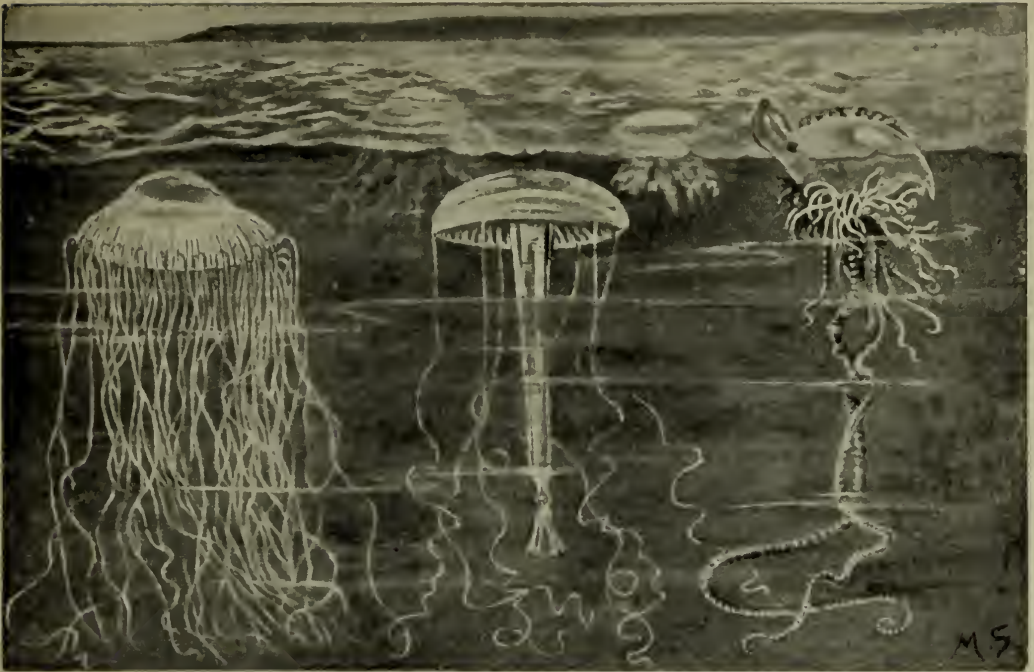
As instruments of flight these extensible folds of skin and abnormally developed fins are primitive implements, but they are as interesting to the student of zoölogy as true wings. For here, obviously, we get a picture of the way in which flight, the most marvelous of all forms of locomotion, first had its inception. The travels of the so-called flying animals, animals which use a parachute, reproduce the earliest efforts of primitive animals to rise superior to the pull of gravity. Evidently the experiment was not confined to one type, for the flying lemur is very ancient, surviving from a type which emerged before the insect-eaters and the pouched animals were evolved.

From some insect-eating animal which had begun in this way the first bats sprang. They are, of course, true fliers, more wonderful fliers than most of us realize until we know of a barbarous experiment once



FISH-LIKE CREATURES WITHOUT LIMBS

Lampreys that live upon the juices of fish.



WATER HELD TOGETHER IN A SORT OF WEB, MANY FORMS TRAILING LONG AND SINOUS APPENDAGES

tried to test their powers. Bats which had been rendered sightless were turned loose in a room crossed in many places by threads of cotton. But not a bat collided, either with the threads or with any other article in the room. A day-flying bird will blunder ludicrously if turned into the night; a nocturnal bird is dazed and lost by daylight. Yet these sightless bats flew up and down and across and across this maze without once touching a single obstacle. They have some sense of direction which we do not understand. Still, expert fliers as they are, their wings are not true wings in the sense that a bird's wings are. Bats have enormously extended the bones of the hand and enclosed them in a membrane, which continues along the arm and sides of the body and joins the hind legs — turned with knees outward — to the longish tail. The toes are free, and by these the bat hangs himself up; the two thumbs also are free, and serve as hooks. But the whole equipment is only an extension of the parachute principle, which must once have been on the way to perfection in the flying lemur. The inspiration lay in that extension of the bones of the hand. It

gave the bat an advantage over all other living creatures save the birds. Well has the bat profited by his advantages. Few of us realize how numerous these flying mammals are. Bats are relatively few, not, indeed, in individuals, but in number of species, in North America, but they teem in warmer climates. There are close upon eight hundred known species, and they reveal as great diversity of form and feature as is found anywhere in the whole of animal creation.



"THE FIRST ELECTRIC MACHINE," THE ELECTRIC EEL
A discharge from which is powerful enough to stun a man.

FACE OF A FLOWER-
NOSED BATHEAD OF THE LONG-TONGUED VAMPIRE WITH PRO-
TRUDED TONGUEHEAD OF INDIAN FALSE
VAMPIRE BAT

They are divided into two classes — the insect-eaters, which are by far the more numerous, and the fruit-eaters. The latter include the flying foxes, great bats with a wing-spread of from four to five feet, which are so abundant in India as to cause serious damage to cultivated crops. But there is a third class, the bloodsuckers, the true vampires, which, descending with fanning wings at dead of night upon a sleeping man or animal, shave away the skin with their razor-like teeth, then draw the blood until gorged. This bat has its apologists, but the fact is that the stomach of the vampire is simply an elongated tube, adapted only to the reception of blood, and not to a solid diet.

With bats we leave our survey of the evolutionary processes evidenced before our eyes. This sketch is necessarily casual and haphazard, but sufficient examples

have been cited to show that the pageant of life before us is not composed of animals of one dead level of age and attainment. Among some of the lowliest forms of life we find forms most to be pondered over, those living mile-stones which show us the route by which the rest have come; and with them, sharing the same area, often the same food, the same risks and vicissitudes, are the highest yet along the same line of progress.

The day is surely coming when many of these links will forever have been snapped. Civilization with its sanguinary zeal — though tempered a little with consideration in these latter days — is stamping out wild life wherever she sets her foot. It is well that we should glean, while we may, something of the romance and wonder that still remain to us in the lives and lineaments of such wild creatures as still survive.



THE FLOWER-NOSED BAT OF THE SOLOMON ISLANDS

